QUANTUM PHYSICS

FOR BEGINNERS

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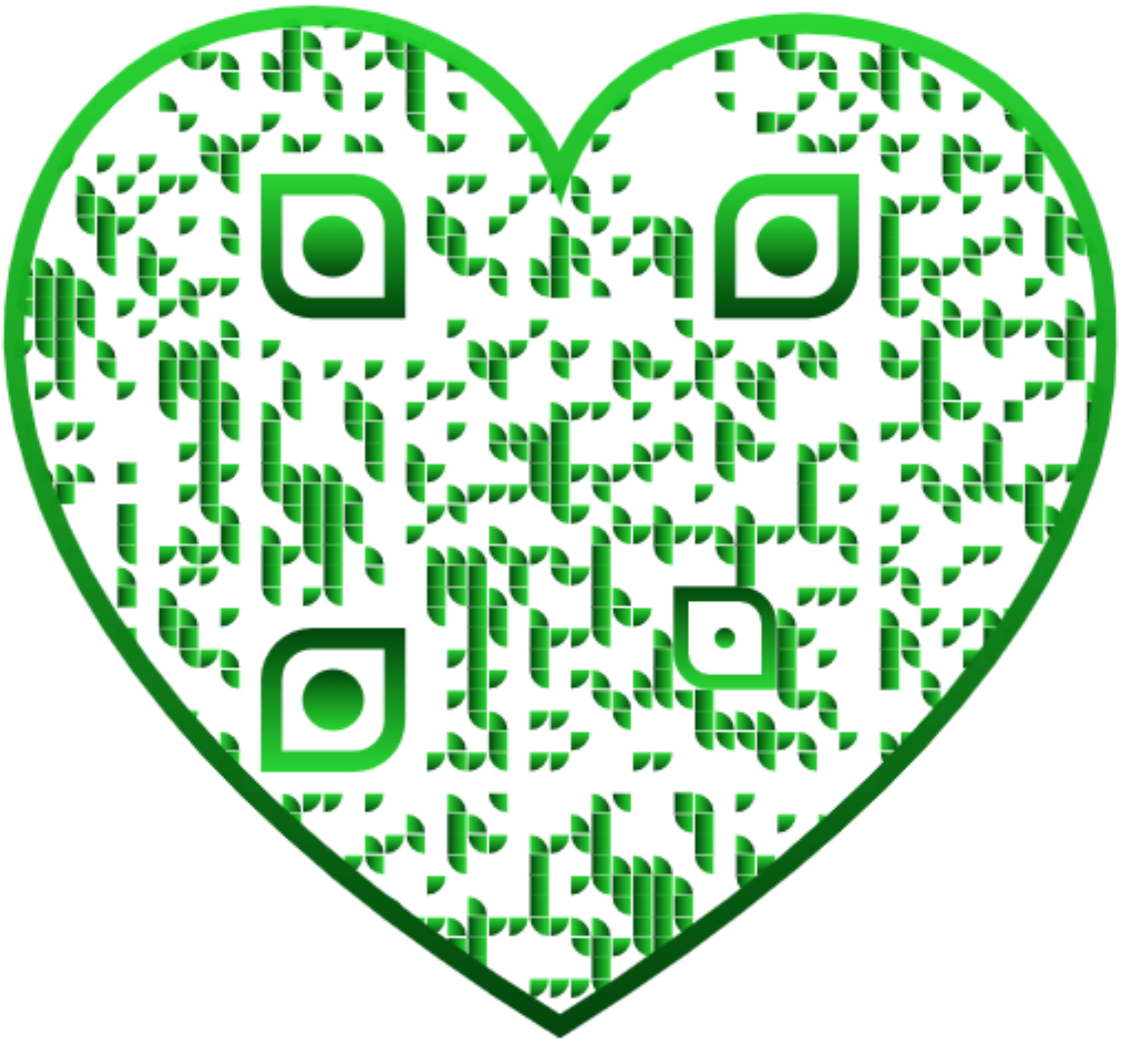
Discover the Mysterious Link Between Quantum Physics & Spirituality. Basics of Mechanic Principles, Theory of Relativity & Theory of Entanglement Made Easy for You

THOMAS COSMOS



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INTRODUCTION

Quantum physics is one of the most important but also most complicated branches of natural sciences. It is difficult to grasp the main concepts without getting bogged down in mathematics and equations. Nevertheless, giving a brief overview of this challenging subject should be an interesting challenge for both beginners and experienced physicists.

The notion of quantum physics was first introduced to explain some specific phenomena that were not described by classical physics, mainly atomic spectra. The idea behind it was that atoms consist of electrons revolving around the nucleus in stable orbits. In 1897 the German physicist Max Planck came up with a new approach to explain black body radiation (Planck Radiation Law). Planck postulated that light energy is emitted in discrete units, called quanta. Later on, Albert Einstein was able to show that this was not just an effect related to light, but applies to all matter particles. He gave a theoretical description of quantum particles in 1905. The mathematical framework for these quantum particles was created by Niels Bohr in 1913.

The quantum notion is based on the dualistic ideas of wave and particle. This is quite revolutionary when compared to classical physics, where things are either wave-like or particle-like. Bohr provided a model that also accounts for classical physics. The idea is that the composition of particles (e.g., electrons or protons) can be described as both a particle and a wave at the same time. This is known as complementarity.

A quantum particle is not exactly what you may have thought it to be. A particle does not have a position but rather an energy distribution, which can be visualized as an energy surface. A classical particle has a defined position and velocity, so in its idealized description, it can be seen as having a value for its position at every moment in time. A quantum particle with position x and velocity v is written as a wave function. In contrast, a position in classical physics can have any value. A particle has one specific value for x at each particular point in time.

It's tough to describe the state of a particle in a way that's better than

representations of water waves (which we usually think of as waves) or light waves (that we assume to be particles). For example, a wave function describes the probability of finding an electron at a certain distance from the nucleus. The probability of finding it within the volume around the nucleus is given by its square.

The wave function describing an electron in a hydrogen atom is given by.

So, the probability of finding the electron at a distance of 0.5 from the nucleus is given by, which means that it is zero! The electron does not have this precise location but it has to be somewhere within the volume around the nucleus.

In comparison, in classical physics, this would be like having an imaginary box with exact values for x for any value of t.

What about other fundamental particles such as protons and neutrons? In general, we cannot know where they are located exactly because they are described by a wave function as well. They are said to have quantum superposition which basically means that they can be anywhere within a certain range. Within this range, the energy of an electron can reduce substantially, since it is contained by the wave function.

WHAT IS QUANTUM PHYSICS?

For the vast majority of people, the term “Quantum Physics” is closer to “rocket science” than it is to “the wonders of the universe.” And that’s a real pity. Most of you might think of tedious formulas and explanations when thinking of physics—but the truth is that both “traditional” physics and Quantum Physics are pretty much the sciences that hold the secrets to the universe: the why’s and the how’s the entire cosmos works.

Quantum Physics will bring a whole new perspective into your life on so many subjects that it is impossible to ignore, regardless of what you do for a job. How could you react when you know that Quantum Physics is at the foundation of what you are, in the background of your fate spinning your life, and at the core of your very way of “functioning” as an intelligent being of the universe?

Almost borderline between science and spirituality, Quantum Physics might finally be able to explain the unexplainable and help us transgress the borders of thinking that have been limiting us thus far and bring us closer to the essence of the world.

This science, what it is, where it came from, and the fundamental assumptions that underpin it. We invite you to discover the beauty of a study discipline that has been long considered a mystery and an impossible topic simultaneously, step by step.

Let’s dive in and uncover the basics of Quantum Physics!

What Exactly Is Quantum Physics?

To understand what Quantum Physics is, you must first go to the “mothership,” i.e., physics. For many people, physics is that boring subject in school you have to be a real “nerd” to like: the one that is even worse than mathematics and even more difficult to understand than chemistry.

For many other people, physics revolves around mechanics, or, in layman terms, “how cars work.” While it is true that physics deals, among many other things, with how cars work, it also deals with a little bit more than how

cars work. It is also worth noting that mechanics is only one branch of physics, but lays at the very foundation of car-making, alongside electronics —another physics branch.

The etymology of the word “physics” is pretty fascinating: it comes from the Greek word “physique,” which is used to mean “knowledge of nature.” As such, the definition of physics is tightly connected to nature and getting to know it.

Many define physics as a natural science that studies matter, how it behaves through space and time, and how it connects to energies and forces.

These each deal with a distinct feature of matter and other sorts of value in a different way (such as in nuclear physics, for example, which studies how atomic weight behaves in different contexts).

In addition to this categorization, you may also find people talking about classical physics and modern physics, which is a way to look at this natural science from the perspective of its evolution in time. So, where does Quantum Physics lie in this entire paradigm, you may ask?

Well, you see, quantum physics is a bit of an odd “animal” because it is sometimes used as a synonym for modern physics. It only comes as both a continuation of traditional physics and as an antagonist as well. Although most modern physics revolves around quantum theory, it is worth noting that, at large, it is still considered to be only a direction of modern physics. To better understand the relationship between modern physics and Quantum Physics, consider the fact that two significant theories and theoreticians marked the beginning of modern physics. Planck’s constant is the most famous one, and it entailed that the energy and frequency of light are proportional, which led Einstein to postulate that light exists in small quantities of energy called “photons.” Albert Einstein, on the other hand, had a major work related to the theory of relativity and the photoelectric effect.

The first postulates, in short, that gigantic objects can be the origin of a distortion in space and time, which is sensed as gravity. As mentioned above, the latter says that light does not exist in waves, but in quanta (small pockets of energy). If “big” physics deals with things you can more or less see (or at least perceive, especially if you run experiments), Quantum Physics deals

with the tiniest parts of matter. This is its actual definition: the science that deals with the atomic and subatomic levels of significance. That might not sound like much. However, Quantum Physics has gone so in-depth (and continues to do so) that it might be the one to explain everything in the universe finally. Everything we've never known. All the questions we always sought an answer to—the very essence of life. Can you think of Quantum Physics as a boring topic when you look at it from this perspective? Do you know it is the science that will finally help us understand so much our place in the universe, more about ourselves, and where all of this is leading?

Not only does it appear to hold the key to all the things we never managed to achieve (like teleportation, or understanding fate and destiny, for example), but it is also a contradiction to a lot of very well-established theories, including that of general relativity brought forward by Albert Einstein himself. There is a war for knowledge out there, and Quantum Physics just "happens" to lie at the very core of it. We bet we made you curious!

History

During the 19th century, crystallographers and chemists tried to prove the existence of atoms. Still, it was not until the beginning of the 20th century that they were finally brought to light, thanks to X-ray diffraction. To model them, the quantification of the matter is a compulsory passage, which gives rise to Quantum Physics. In 1900, Max Planck hypothesized that the exchanges of energy with case took place in small quantities; "the quanta."

Louis de Broglie then initiated Quantum Mechanics, which makes it possible to model the atom correctly. Quantum Physics ends up absorbing all areas of classical physics in one discipline. Particle accelerators then showed that atoms were composed of more elementary particles, like the proton or the neutron, themselves composed of quarks. It is the quantum field theory constructed from quantum electrodynamics, which will describe the set of elementary particles.

The Beginning

Quantum Physics has brought a conceptual revolution with repercussions up to philosophy (questioning of determinism) and in the literature (science fiction). It has enabled several technological applications: nuclear energy,

medical imaging by nuclear magnetic resonance, diode, transistor, integrated circuit, electron microscope, and laser. A century after its conception, it is widely used in research in theoretical chemistry (Quantum Chemistry), in physics (Quantum Mechanics, Quantum Field Theory, Condensed Matter Physics, Nuclear Physics, Particle Physics, Quantum Statistical Physics, Astrophysics, Quantum Gravity), in mathematics (formalization of field theory) and, recently, in computer science (Quantum Computer, Quantum Cryptography). It is considered, with Einstein's general relativity, as one of the major theories of the 20th century.

Quantum Physics is known to be counter-intuitive, to shock common sense, and to require arduous mathematical formalism. Feynman, one of the greatest theoreticians specializing in Quantum Physics in the second half of the 20th century, wrote:

"I think I can say that no one understands Quantum Physics."

The main reason for these difficulties is that the Quantum World (limited to the infinitely small, but which can have repercussions on a larger scale) behaves very differently from the macroscopic environment to which we are accustomed. Some fundamental differences that separate these two worlds are, for example:

Quantification: a certain number of observables, for example, the energy emitted by an atom during a transition between excited states, is quantified. That is to say that they can only take their value in a set of discreet results. Conversely, classical mechanics most often predicts that these observables can take on any amount continuously.

Wave-particle duality: the notions of wave and particle, which are separate in classical mechanics, become two facets of the same phenomenon, described mathematically by its wave function. In particular, experience proves that light can behave like particles (photons, highlighted by the photoelectric effect) or like a wave (radiation-producing interference) depending on the experimental context; electrons and other particles can also behave in an undulatory manner. In particular, it is impossible to obtain high precision in measuring the speed of a particle without getting mediocre accuracy in its position, and vice versa. This uncertainty is structural and does not depend on the care taken by the experimenter not

to disturb the system; it constitutes a limit to the accuracy of any measuring instrument.

The observation influences the observed system: during the measurement of an observable, a quantum system sees its modified state. This phenomenon, called wave packet reduction, is inherent in the size and does not depend on the care taken by the experimenter not to disturb the system.

Non-locality or entanglement: systems can be entangled so that interaction in one place in the system has immediate repercussions in other areas. This phenomenon contradicts the special relativity for which there is a speed limit for the propagation of all information, the speed of light; however, non-locality does not allow data to be transferred.

Contra factuality: events that could have happened, but did not occur, influence the results of the experiment.

Between 1925 and 1927, several physicists succeeded in assembling the pieces of the giant Quantum Physics puzzle in a few years. First of all, Louis de Broglie and Erwin Schrödinger reasoned that if light, which is a wave, can exist in the form of energy packets, then conversely, perhaps particles like electrons, which are of small energy packets, can behave like a wave. They thus developed the wave functions.

A particle can, therefore, exists in several superimposed states, waves, or particles. It is the principle of superposition. Then, Werner Heisenberg introduced the principle of uncertainty. In Quantum Physics, one cannot precisely measure two values of the same particle (for example, its position and its speed). If one of the two elements is measured correctly, the other will necessarily be fuzzy. Wolfgang Pauli defines the exclusion principle, according to which 2 electrons can never be in the same place in the same state. Niels Bohr, of whom Heisenberg and Pauli were disciples, offered a unified theory of Quantum Physics.

But Albert Einstein remained very skeptical. He considered that randomness cannot be a fundamental principle of physics. If we cannot precisely measure two values of a particle, this does not mean that they are not measurable, but simply that we do not yet know how to do so. He, therefore, believed that quantum physicists used probabilities because their incomplete theory did not

allow them to describe the observed phenomena correctly. Long debates opposed him to Niels Bohr, during which Einstein will exclaim, “God does not play dice!” The debate was raging.

In 1935, Einstein, Podolsk, and Rosen raised the following paradox. The state of particles is random, according to quantum physics principles. However, as long as they are closely linked (this is entanglement), it is possible for particles located in places very far from space to always have precisely the same state at the same time as if they were communicating instantly. These would imply that they transmit information faster than the speed of light. In the universe of Albert Einstein, as in our daily reality, it is absurd. Quantum Physics must, therefore, necessarily be incomplete.

The debate remained as it was until 1964 when John Bell demonstrated in Geneva that Einstein’s ideas on the incomplete aspect of quantum theory contradict the very predictions of this theory. One of the other must necessarily be false. John Bell, therefore, proposed an experimental method to respond to this paradox. This experiment could not be carried out conclusively until 1982 by Alain Aspect and his collaborators in Paris. It irrefutably demonstrated the correctness of the quantum theory.

The Second Quantum Revolution

The vast majority of physicists remained indifferent to the aspects most contrary to the intuition of this new theory until the 1990s. We then began to realize the potential applications of quantum physics in our daily life. In Geneva, Nicolas Gisin’s team teleported photons into the optical fibers of the Swisscom network over tens of kilometers. Then Peter Shor, in the United States, showed that by entangling a hundred particles, we could break all the security codes existing today: those of banks, companies, armies. Quantum Cryptography would then be the only genuinely inviolable mode of data protection, and that’s how Quantum Physics comes into our daily lives.

Quantum and the Living

Are there phenomena in the living world obeying these rules of the infinitely small? In recent years, studies in various areas of biology indicate that this is the case. These results go against the generally accepted idea that the macroscopic world is too chaotic to allow quantum decoherence effects. The

living would be able to take advantage of this disorderly agitation of particles, at least as far as photosynthesis is concerned.

The receptors for smell seem to depend on the tunnel effect to transport electrons inside the odorous molecules, which makes it possible to distinguish them from other structurally analogous units. Specific bacterial protein structures behave like Primitive Quantum Computers, calculating the best electron transport channel among all possible paths.

Recent work on photosynthesis has revealed that the entanglement of photons plays an essential role in this fundamental operation of the plant kingdom, a phenomenon we are currently trying to imitate to optimize the production of solar energy.

The adhesion to the surfaces of the set of the Gecko’s works, thanks to the forces of Van Der Waals, interactions of quantum nature, involve virtual particles without any classical molecular interaction. This phenomenon is also being studied for military and civil applications.

The physicochemical reactions underlying photosynthesis are well understood. Still, the efficiency of the process in biology remained an enigma until the discovery of the supramolecular coordination of these operations by quantum coherence, which is a foreign influence.

QUANTUM THEORY

The ultraviolet catastrophe was one of the most prominent indicators that light has to be more than just a wave.

This name might seem like an exaggeration, but the ultraviolet catastrophe was disastrous for the conventional thinking about the physics of light.

In the previous chapters, we talked about how objects radiate heat, specifically, the amount of heat that an object radiates over time is proportional to its temperature, but there is more than just heat.

Objects also radiate energy that covers a wide range of frequencies on the electromagnetic spectrum, basically all different kinds of light.

Let’s now consider a blackbody, which was first defined by Gustav R. Kirchhoff in 1859 as an object that absorbs all radiation falling upon it, without reflecting any, and radiates energy accordingly. Such a conception of an ideal blackbody was crucial for understanding heat radiation and its laws. Since a complete blackbody does not exist in nature, it had to be constructed.

It is possible to predict the intensity of the energy coming from a blackbody (blackbody radiation) based on its temperature.

When the physicists developed an equation to evaluate this intensity, starting from the assumption that light is a wave, they found the limits of this theory.

The equation that was used, known as Rayleigh-Jeans law, predicted that the higher the frequency of the radiation, the higher the intensity, and that matched with experimental results well, but only up to a certain point.

Once the frequency of light reached the ultraviolet range (or even higher), the Rayleigh-Jeans law showed its limits, not fitting the results of the experiments at all.

The Rayleigh-Jeans law agrees with experimental results at large wavelengths (low frequencies) but strongly disagrees at short wavelengths (high frequencies). The ultraviolet disaster is the name given to the discrepancy between observations and classical physics predictions.

According to the results of the experiments, at a certain frequency, the light would be at its most intense, and after that, the intensity would drop as the frequency increased.

The warmer the object, the higher the frequency of the peak intensity, but there was always a peak. According to wave theory, it wasn’t supposed to be in this way!

Even worse, summing up all the contributions of higher and higher frequencies to calculate the total power emitted by a blackbody, the Rayleigh-Jeans law predicted that we would reach infinite power, which is in direct contradiction with the conservation of energy principle.

The ultraviolet catastrophe highlighted that something was wrong with the way physicists were thinking about light.

The catastrophe was resolved in 1900 using an equation derived by German physicists Max Plank. This equation gives the correct radiation at all frequencies and was a foundational aspect of the development of quantum mechanics in the early 20th century.

We can say that Planck's radiation law is a mathematical equation that describes the distribution of energy that reflects the energies of blackbody radiation (see Fig.2).

Planck’s law is actually very simple, but the concept was based on something completely new at that time. According to Planck, electromagnetic energy takes the form of tiny, discrete packets, called quanta. This might not sound intuitive, but the main idea is that after a certain point, you can’t divide energy into anything smaller than these quanta packets.

The energy (E) of each quantum is equal to the frequency of the light (f), times a very small number called Planck’s constant (h), which I’ll explain more in detail later.

Using Planck’s radiation law to predict the intensity of a blackbody allowed physicists to predict the experimental results perfectly, including those peak intensities.

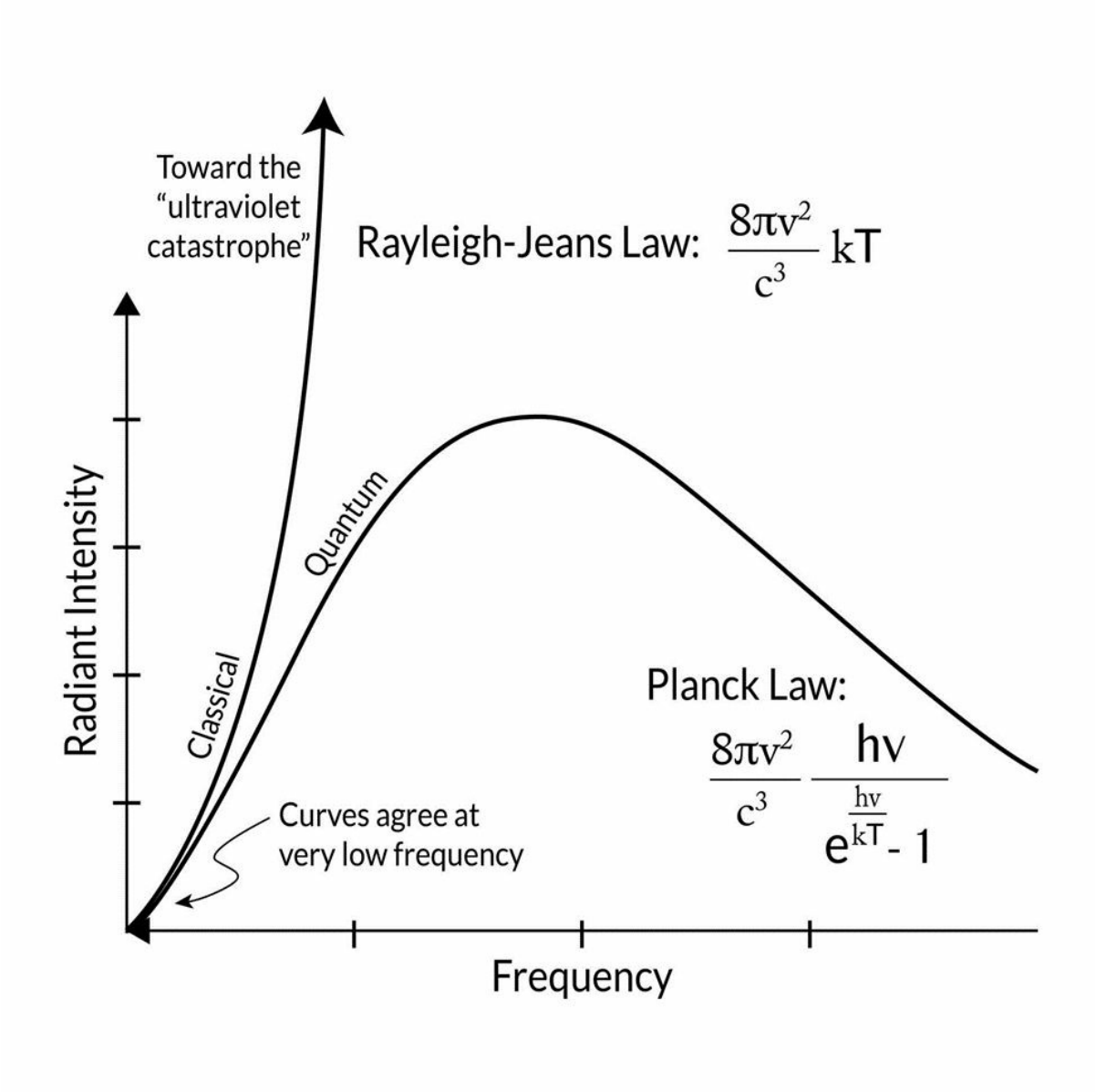


Fig.2 - Ultraviolet catastrophe vs Planck Law

Ok, but how did Planck actually manage to solve the ultraviolet catastrophe?

Planck assumed that the origin of the radiation is atoms in an oscillation state and that the vibrational energy of each oscillator can assume only discrete values. Also, Planck thought that when the oscillator switched from a higher state of energy (E1) to a lower state of energy (E2), the amount of differential energy (E1 - E2) or the amount of quantum radiation was equal to the product of frequency (v) and Planck's constant (h), previously introduced: E1 - E2 =

hv.

In this book, we will not go into the details of how Planck determined this constant or the mathematical demonstration to derive the formula.

In the wavelength region from to + (where + signifies a wavelength increase), Planck's law for the energy E radiated per unit volume by a blackbody cavity is as follows:

$$E_\lambda = \frac{8\pi hc}{\lambda^5} \times \frac{1}{\exp(hc/kT\lambda) - 1}$$

Where:

$$\mathrm{h} = \text{Planck's constant}$$

$$c = \text{Speed of light}$$

$$k = \text{Boltzmann constant}$$

$$\mathrm{T} = \text{Absolute temperature}$$

The wavelength of emitted radiation is inversely related to its frequency or c/v.

The Planck constant has the value of 6.62607015 1034 Js (joule-second). Explaining how Planck determined this constant requires a mathematical demonstration to drive the formula, which would be too advanced for this book. Let's just say that he was able to compute them based on blackbody radiation data.

What Planck's formula basically demonstrates is that, in the case of the blackbody, with a temperature at several hundred degrees, we can see in the electromagnetic spectrum that most of the radiation is infrared. If the blackbody reaches higher temperatures, the total energy released increases, and the emitted spectrum shifts towards shorter wavelengths. This means that

at higher temperatures, a blackbody radiates mostly visible light.

NEWTONIAN VS QUANTUM PHYSICS

In order to understand the distinctions between classical and quantum physics, first we need to briefly establish what both of them are. Classical physics goes by many names such as conventional, Newtonian, etc. If put simply, it is a kind of physics that does not use principles of quantum theory or quantum mechanics. It is devoid of anything "quantum." Thermodynamics, Newtonian mechanics, electricity, magnetism, and Maxwell theory are some of the leading fields that come under the label of classical physics. The issue is that when laws of Newtonian Physics are applied to the microscopic world (subatomic level), they start failing. This leads us to formulate a new type of physics that can explain the microscopic world just as clearly as the macroscopic is explained by classical physics. And this is where quantum theory comes in.

Quantum physics is a branch of physics that provides a fundamental outline in order to explain the behavior of atomic and subatomic particles, namely,

electrons, positrons, neutrons, and even smaller particles.

Scientists have this ‘rule of thumb’ that if Planck’s constant is involved in an equation or calculation, then it is quantum physics, otherwise, it’s classic physics. Another simple and convenient distinction between the two is that classic physics studies the macroscopic world. Things like motion, work, displacement, collisions, sound, etc., and mostly the things that we see around us, are discussed in Newtonian physics. Like we all knew which principles of physics made generators and refrigerators work, after taking high school physics. All the things and phenomena that we commonly come across in our day-to-day lives are classic physics. On the other hand, quantum physics has more of a subatomic or microscopic approach. Photons of light, positrons, quantum realm and Higgs bosons are not the kind of things that we see around us every day because they reside in the subatomic realm.

Classical physics or Newtonian physics and quantum physics are two distinct types of physics, and it is important to understand what differentiates one from another. Once we understand the difference between both types, only then our mind will be able to separate them. However, human minds understand and learn things better when they are explained with the help of analogies and examples. That is exactly how the differences between the two primary disciplines of physics are discussed here in the following paragraphs.

For now, let's look at some of the major differences between the two:

1. Path Prediction: According to classical physics, an object chooses the easiest path, and the path it chooses is also the only one, that sets a path for the object to move. As it might be applicable and accurate to large objects, quantum physics, however, does not work like this. In the subatomic world, particles also choose the easiest, resistance-free path, but the paths can be multiple that cannot be predicted. For instance, you have 8 cats and 7 cat beds, then according to classical physics, it is predicted that 2 cats will have to stay in one bed. Again, this is not the case with quantum physics, of course, as there is an infinite number of electrons in only one cat bed. The whole perspective has to change.
2. Probability: As the first point suggests that behavior or paths of subatomic particles cannot be predicted, they can be for macroscopic objects in classical physics. This means that quantum physics utilizes probabilistic

models for future predictions. The use of probability is low to none in classical ways, but quantum physics makes use of it extensively.

3. Macroscopic vs Microscopic: This is probably the most easily understood concept and a distinct point of differentiation between the two physics: quantum and Newtonian. Even in the subatomic world, quantum physics is expanding and it’s not only restricted to studies of particles but extensive discoveries are done on particle fields as well. And there is a whole new discipline under quantum mechanics dedicated to only surrounding fields of particles; this discipline is known as quantum fields. Clearly, no such concept is there because all of the objects of study are quite reachable.
4. Simultaneous Calculations: In classical physics, direction, speed, and position of an object can be determined easily at the same time. Contrarily, no such thing is in quantum mechanics, of course, because we are well aware of Heisenberg's uncertainty principle. The position and velocity of a particle cannot be determined simultaneously. People initially pointed out that this could be because we do not have the equipment to determine them at the same time or it’s some kind of human error. But Heisenberg explained this point quite well in his extensive calculations in his uncertainty principle.
5. Continuous vs. Discrete: We are well aware of discontinuity in quantum physics. It was the first distinction made between the two. The hydrogen spectrum was the first application of the discrete nature of electromagnetic radiations. It is because the spectrum gained by the excitation of hydrogen electrons was in the form of discontinuous colored lines instead of continuous colors.
6. Wave or Particle: Quantum physics reiterates the dual nature of everything. If a particle moves like a wave and has wave properties (frequency, wavelength), then a wave can also have particle properties too (mass, volume, position, momentum, etc.). It has been proven by many experiments as well. At the quantum level, both particle and wave properties of an object are clear, but in the macroscopic world, it's not as evident. For instance, imagining the moon to have a frequency is a bit difficult, but it does not mean it's not there. On the other hand, classical physics divides objects and assigns them as either waves or particles, with no duality whatsoever. Many experiments clearly suggested the dual nature of particles and waves, and could not be explained by classical

physics, so the emergence of a new discipline of physics to understand those peculiar results of experiments was a necessity.

The above-mentioned points are explained in detail in the following paragraphs.

In classical physics, the exact location, displacement, and velocity of an object can be predicted easily. On the other hand, uncertainty and probability are the main pillars of quantum physics because one can never confidently predict the behavior of a subatomic particle, for instance, its path, velocity, position, etc. If the velocity of a particle is determined, then the position of this particle can never be pinpointed and vice versa. It means that one quantity does remain a mystery or uncertain. In addition to this, the path followed by a particle after position determination cannot be predicted as well.

However, in the macroscopic world around us, one can predict the exact location of an object, its speed, direction, where it is going, etc. Take the moon, for example, today we are well aware of how much time it's going to take to complete one revolution around the earth. Likewise, we can also predict the date on which the crescent will appear, and we can do so with certainty (not something we have the luxury of in quantum physics) and for multiple decades in the future, too. The same is the case with the earth's revolution around the sun, climate, weather, volcanic eruptions, etc. The low of rivers can be calculated using simple mathematical and physical principles of discharge, volume, and drainage pattern. It won't be wrong to say that in these forecasts, there is some amount of uncertainty, too, but as compared to the quantum world, the uncertainties are negligible.

As already mentioned, the uncertainty principle of Heisenberg throws light on the fact that paths of subatomic particles cannot be predicted, and they cannot possess some rigid and numbered paths to follow, as suggested by classical physics. There is a cloud of probability around the nucleus of an atom and an electron can be found anywhere in that cloud. On the other hand, these types of predictions are quite common in classical physics and a classical model of atoms suggests that there are some set paths around the nucleus on which electrons can be found, and their direction, speed, momentum, etc., can be determined with little to no error.

Even with random electronic paths and probabilistic models, we are still certain about one thing, the behavior of a particle according to quantum physics. There are multiple discrete sets of paths for an electron or any other particle to move around a nucleus. Their discrete nature is explained by particle theory and proven by the hydrogen spectrum. This distinction factor of quantum physics has also been elaborated in chapters one and six in detail where Heisenberg's uncertainty principle is discussed. This principle provides the basis of quantum mechanics as we know it.

Technological Differences

A very advanced and recent application of quantum physics is the quantum computer that is, according to many sources, almost 100 million times faster than a normal classical computer. The calculations and simulations created by quantum computers cannot even be imagined by a classical one. Classical computers employ binary numbers like zero and one to make their calculations. Quantum computers also use binary numbers, but they have an edge over classical computers, i.e., they use entanglement and superposition of binary numbers, which enable them to perform operations more efficiently and faster. So unlike classical computers, quantum computers can easily represent both one and zero at the same time. In the world of computing, Alan Turing is the father of classical computers; He developed an advanced machine for decoding messages from the German army during World War II. Similarly, David Deutsch is considered the father of quantum computers. He took Alan's machine to more advanced levels and applied quantum mechanics to it. His main research is in quantum algorithms and constructor theory.

Another stark difference between quantum and classical physics is related to quantum computing. The temperatures at which quantum physics phenomena operate are extremely low. For instance, quantum computers operate between -200 to -300°C. Any temperature more than that and the physics shift to classical phenomena. Despite being the most advanced type of physics, sometimes it gets difficult to observe the world at the quantum level. Evidently enough, classical physics does not have this type of thermal restriction. Most of the phenomena can conveniently be seen at room temperature.

Some Advanced Concepts

Electron Spin

Adding to the differences is the discovery of electron spin, which was a big achievement of quantum physics. A group of physicists proposed that apart from revolving around the nucleus, electrons also spin along its central axis. The spin of the electron is a property of quantum particles, and it is a type of angular momentum. The spin can be clockwise (up) or anticlockwise (down). This is another difference between classical and quantum physics. According to classical physics, electrons do not spin while quantum physics says otherwise. The spin of electrons has been proved through experiments as well. When two scientists, Stern and Gerlach, opened a stream of electrons under a magnetic field, according to the concepts of classical physics, the stream of electrons should have hit one spot on screen, instead it made two spots, hence, proving the spins of electrons (up and down).

Quantum Entanglement

The concept of state or particle entanglement is purely quantum physics and cannot be explained in classical physics. According to quantum physics, there is a physical phenomenon called quantum entanglement which explains that states of a group of particles are superpositioned. These particles cannot be considered individually, even if they are light years apart from each other, they act as a whole. For instance, two electrons in the same system have opposite spins, they are million years (should it be “light years”?) apart from each other, yet if the spin of one electron is measured, the spin of the other electron will suddenly snap to the opposite direction. There is this invisible strong relation between these particles that is hard to decipher. In classical physics, however, no such relation between objects is observed. This is also one of the concepts in quantum physics that people find spooky.

Quantum Tunneling

Quantum tunneling is a phenomenon of quantum mechanics which explains the propagation of a particle through a barrier of potential difference. In quantum physics, tunneling is possible. So basically, particles or waves do not have to pass over the barrier of energy but tunnel through it. This theory is actually quite useful in the development of microelectronics and

microscopy. Contrarily, classical physics, mechanics do not support this idea and states that particles do not have enough energy to go through the barrier.

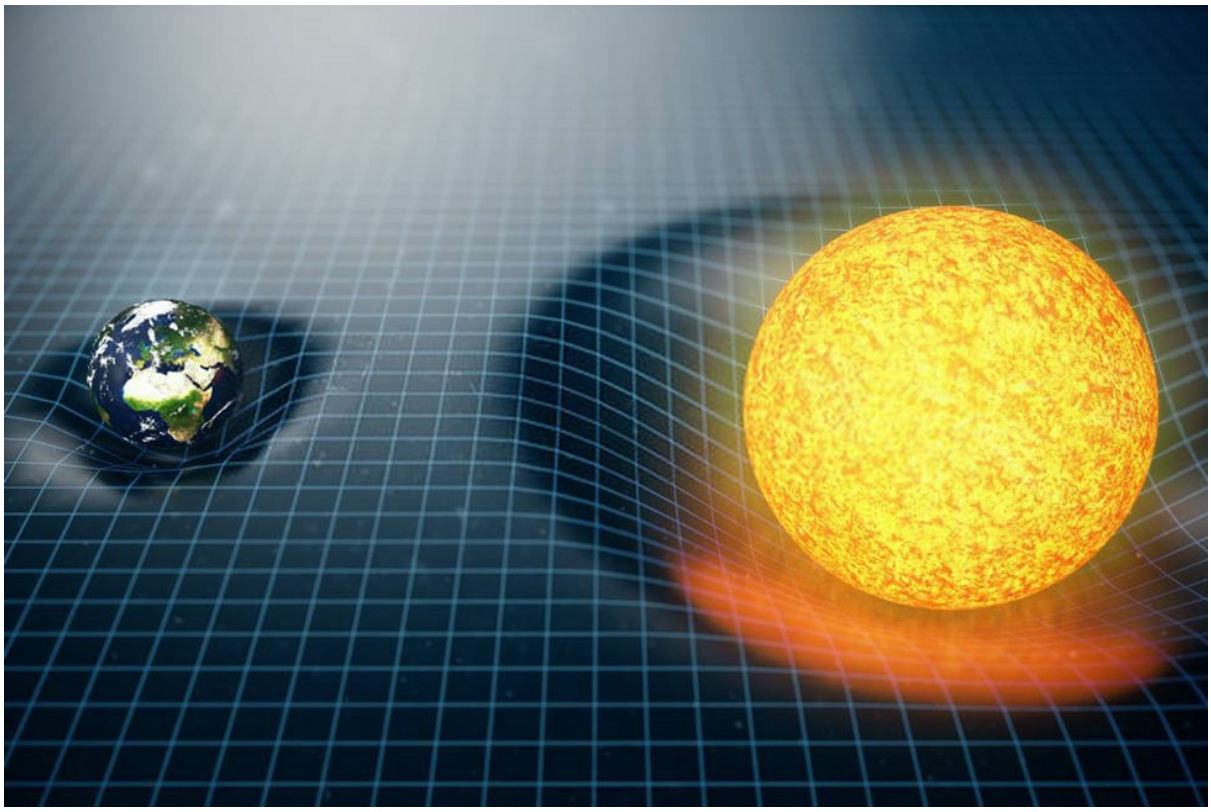
Particle in a Box

Particle in a box is a hypothetical system presented by quantum physics to illustrate the difference between classical and quantum theory. If there is a particle inside infinite walls of the potential barrier, it will have specific allowed energies. Then there is also the concept of position and velocity determination uncertainty. The energy of the particle cannot be zero, which means it's always moving. In classical physics, the particle in a box is described to have any energy or speed (not specific) and its position can be certain, too. If the box gets smaller, then at the micro-level, classical physics fails to explain the particle's behavior and quantum physics comes in.

Harmonic Oscillations

The harmonic oscillator is a system explained by classical physics. If this system is displaced from its resting position, then it will encounter a force that will restore its original position and this force is proportional to the displacement “x” of the harmonic oscillator. Similar to the particle in a box system, the classical harmonic oscillator can have any energy, but the one at the micro-level cannot behave like this. At a very small level, quantum physics has to intervene to explain the behavior of the harmonic oscillator, the specific energy and velocity it can have.

RELATIVITY THEORY



Einstein’s Life and Achievements

One cannot discuss the theory of relativity without writing about Albert Einstein. He was a theoretical physicist who was born in Germany, but later became a US citizen. He is famously known for many of his scientific achievements, such as mass and energy equivalence equations, and General and Special Theories of Relativity. He also made some attempts to explain quantum physics and gave a comprehensive explanation of the photoelectric effect and Planck's quantum theory. He always had a unique strategy in mind to solve the problems of physics. Initially, Einstein argued with several theories of quantum physics and gave out his own theories and explanations, but they were not accepted. His theories about quantum physics might not be well accepted, but his remarkable work does have a deeper connection with quantum physics. It's just that his area of expertise was different.

When he started his work in the scientific community, Einstein immediately felt the lack of explanation for many phenomena in classical physics. This is one of the reasons why he presented his Special Theory of Relativity. He wanted to conjoin classical mechanics and magnetic field theory. Einstein solved many issues related to statistical mechanics because a better explanation using statistics will help quantum theory. So, in this way, he also threw light on the Brownian motion of molecules. His work also includes the study of light and its relationship with the intensity of radiation. His contribution to light theory pioneered the quantum photon theory of light.

In the 1920s, Einstein was still working on his explanation of the quantum theory and he kept on working on statistical mechanics by developing a monatomic gas model. On top of that, he made remarkable connections in probability and the theory of cosmology. It is roughly the same period when Einstein gave more thought to a unified theory of physics, also known as the theory of everything. He believed, just like many other physicists, that equations for all the forces can be merged together to form a single unified theory that will be valid for all physical forces and a unique solution to all problems.

The approach Einstein adapted to solve the problem of unification was geometrization which was quite different from what physicists normally did. He always had a unique way of approaching different aspects of physics. He kept on working with unification theory, even after retiring. Einstein’s noteworthy discoveries include Relativity, Special and General Theory of Relativity, Evolution of Physics, and research on Brownian Motion Theory. His area of knowledge was quite wide, and he did a good amount of work on non-scientific topics too, writing about politics, society, and philosophy. Some of his famous works are on Zionism, humanism, religion, etc.

Einstein was awarded the Nobel Prize in 1921 for his extensive work on theoretical physics and discovering the best results of the photoelectric effect. He received his prize after one year in 1922. He received several honorary doctorate degrees in medical, philosophy and science from famous American and European educational institutes. He shared his knowledge and views with the world by giving lectures in many countries. Einstein enjoyed listening to music for relaxation in his intellectual seclusion.

Newtonian Physics Before Newton

All the physical phenomena happening in the universe were explained by three universal laws of motion presented by a physicist named Isaac Newton in 1686. The idea that all universes follow these three laws was a bit far-fetched, although they interpreted many of the processes happening on earth at least at a macroscopic level.

These three laws are stated as follows:

An object will remain in an equilibrium state or at rest unless an outside force disturbs its state. This Law of Motion is also known as the Law of Inertia (a property of matter to resist change).

The second Law of Motion states that the rate of change of the momentum of an object is in direct relation with the applied force. It also means that the total force needed to move an object of multiple masses can be calculated easily with this law.

$F=ma$

Where:

F= force

m= mass

a= acceleration

An equal magnitude of forces exists among two objects. If the first object applies force on the second object, it will apply resultant force (of the same magnitude) to the first object and cancel out the result. It is famously known as every action has a counteraction or reaction (action or reaction law).

These laws are quite useful and give the basis of mechanics and gravity to science. But if we have learned anything from quantum physics, it is that the universe is not this simple and explaining multiple phenomena of the universe is even more difficult. Newtonian physics and its laws could not interpret several events, for instance, light and the microscopic world.

In the 19th century, scientists started feeling that light's behavior and propagation cannot be explained by classical physics. But they still tried to

make new discoveries while conforming their results to classical physics principles.

In order to explain the propagation of light through space, they proposed the presence of an ether medium, which is known as the Ether Medium Theory. It was also stated that ether medium has to be solid and brittle for light to move through it fast enough, just like sound waves pass through metals, earth, and other densely packed mediums. Now scientists had to prove the existence of Ether to work further with it which was not going to happen (because there was no Ether). Up until 1886 the Ether hypothesis was still alive but in 1887 some scientists, including Albert Michelson and Edward Morley tried to calculate the change in speed of light propagating through Ether, but no fluctuations in the speed of light were noted. They concluded that there was no Ether medium in the space in the first place. Light moves through space in vacuum (without a medium). This result was quite a leap from what they believed in previously. Scientists knew that they were facing a problem to which classical physics has no solution which means it was time to see physics in a new light.

Special Relativity

Special relativity or special theory of relativity was presented by Albert Einstein in 1905. It is one of the building blocks of modern physics. This scientific theory establishes a relationship between time and space, stating the effects of speed on time, mass, and space.

In Einstein's own book, the theory consists of two main postulates:

The laws of physics do not change in all inertial frames of reference (a frame of reference which has constant velocity and no acceleration).

In the vacuum, the speed of light is the same for all of the observers, irrespective of the observer or light source motion.

As stated earlier, classical physics could not explain the absence of Ether medium or Maxwell's electromagnetism laws; this inspired Einstein to create the special relativity theory and as the name suggests, it is for special unique circumstances. The formulation of the theory of special relativity does not just depend on these two postulates but also on other multiple theories like space homogeneity and isotropy. It should be taken

in mind that, even with some incompetency, laws of motion by Newtonian physics are valid to explain motion at slower velocities as compared to the speed of light, for instance, the motion of the moon around the earth. However, the special relativity theory provides an excellent model for motion at any speed when the effects of quantum and gravity are not considered. This theory of relativity has many outcomes which are all experimentally proven, some of them are time dilation, length shortening and relative simultaneity.

Relative Simultaneity

The concept of relative simultaneity explains that the observation of an event happening at the same time that is separated by space depends on the observer's frame of reference. So, the time of an event is not absolute but relative depending on when the observer sees it happening. For instance, the light reflected from the earth today reaches another planet after 10 years. Then the event I observed today will be observed by the person on Mars when reflected light reaches his/her eyes.

Time Dilation

Time dilation simply states that time is relative and an object moving at a faster velocity will experience time more slowly than one that is not. Although time dilation has been observed, the results showed a small difference; many people argued that they are not true. For instance, an astronaut who spent a year in space, aged slower than his twin on earth. The twin on earth aged milliseconds faster than the twin in space; nevertheless, the evidence was enough to understand time dilation. These changes are best observed at abnormally high velocities like light's velocity, which cannot be achieved by humans just yet.

A 15-year-old boy leaves school and moves at the speed of light for 5 years. When he returns to his normal speed, he would have aged only for those 5 years, but his classmates would be 65 years old. This is because he was moving so fast that he aged slower (time slowed down) as compared to his classmates who were moving around with their normal speed on earth. So, all of his classmates aged normally just as every human does. Again, the results of this outcome of the special theory are conspicuous only in special cases. In

our day-to-day lives, they become very small or undetectable.

Length Contraction

Another interesting outcome of special theory is length contraction. It states the length of a moving object is measured to be smaller than its length at rest. Again, this change in length cannot be observed significantly with objects moving at normal speeds on earth. The differences are negligible but still present. But at the speed of light, the contraction of length of an object is quite noticeable as stated by the special theory of relativity.

General Theory of Relativity

This theory is also called the theory of gravity. According to this theory of relativity, gravity is not just an invisible force. Einstein presented the general theory in 1915 and especially discussed gravity because it was not considered in special relativity theory, so this is an extension to the special theory of relativity. The hiatus of 10 years between special and general theory was spent by Einstein, contemplating gravity and how massive heavenly bodies affect smaller objects or time-space fabric around them.

Isaac Newton explained gravity as the force of attraction between two objects; the larger the mass of an object the stronger would be the gravitational force. Einstein argued with this definition of gravity and described that massive bodies (stars, black holes, etc.) warp time and space. For instance, if a massive ball is put over a trampoline, it will push it down and distort the surface. Now if smaller balls are placed over the surface, they'll slide down just like a massive body will pull smaller objects toward it. This theory of relativity is more applicable and easier to observe. Two experimental pieces of evidence of the General Theory of relativity are as follows:

Gravitational Lensing

The main concept is that light bends while propagating around massive bodies, e.g., black holes. This lensing of light helps cosmologists to observe stars and galaxies obscured by massive space objects. This also helps astronauts to navigate. This is proof of time-space warping by massive bodies. Scientists have also observed the bending of light multiple times,

especially in the case of a supernova.

Mercury Orbit Change

It has been observed that due to the strong influence of the Sun, the path of Mercury is gradually bending as a result of the action of time-space bending. Scientists also predict that eventually, the planets near the sun will collide with each other as the warping of space and time increases.

Gravitational Waves

Einstein predicted the creation of gravitational waves, extremely violent waves in the space-time fabric. These waves were observed by scientists in 2016. These types of waves were detected for the first time by the Laser Interferometer Gravitational-Wave Observatory.

Time-Space Fabric dragging Around Spinning Bodies

As established earlier, massive bodies have a warping effect on time-space. In accordance with this theory of Einstein, scientists believe that time-space fabric should swirl around a spinning planet. They sent a gravity probe to observe these phenomena, and the results were in agreement with Einstein's Theory of Relativity. To illustrate this warping of space and time, Francis Everett said to imagine that the earth is completely submerged in honey so that when the earth rotates on its axis, the honey around it will also rotate around the planet. This is exactly what happiness is to time-space fabric around spinning bodies.

QUANTUM ORIGINS OF THE UNIVERSE

How an initial state develops with time is prescribed by the physical laws that govern the Universe. If the original state of a system is precisely specified in classical physics, then the subsequent motion will be entirely predictable. Specifying the initial state of a system in quantum physics allows one to calculate the probability that at a later time it will be found in any other state. Cosmology attempts to use these physical laws to describe the behavior of the entire Universe. One immediately encounters a problem when applying these laws to the Universe. What is the initial state to which the regulations should be applied? In practice, by using the observed properties of the Universe now to understand what it was like at earlier times, cosmologists tend to work backwards. This strategy proved to be very successful. It has, however, led cosmologists back to the question of the initial circumstances.

The Initial Conditions

As the standard enlightenment of several cosmological problems, inflation (a period of accelerating expansion in the very early universe) is now accepted. The Universe must have been formed in order for inflation to occur, containing some matter in a highly excited state. Inflationary philosophy does not address the question of why this matter was in such a state of excitement. Answering these calls for a theory of the initial pre-inflationary conditions. For such a theory, there are two serious candidates. The first, suggested by Stanford University's Andrei Linde, is called chaotic inflation. The universe begins in a totally random state, based on chaotic inflation. In certain places, the matter would be more energetic than in others, and the observable Universe will be created by inflation.

Quantum cosmology, the solicitation of quantum theory to the whole Universe, is the second candidate for a theory of initial conditions. This sounds absurd at first because classical, not quantum, laws usually follow vast structures (such as the Universe). The theory of general relativity by

Einstein is a classical theory that explains the evolution of the Universe accurately from the first fraction of a second of its life to now. However, general relativity is considered to be inconsistent with the concepts of quantum theory and is thus not an accurate explanation of physical processes occurring on very small scales of duration or over very short periods of time. One needs a quantum gravity theory to explain such processes.

Quantum Gravity Path Integrals

The approach to quantum theory that has been most popular in non-gravitational physics includes mathematical objects known as path integrals. Nobel Prize winner Richard Feynman, of Caltech, introduced Path Integrals. The probability that a system in an early state A will evolve to a final state B is given in the integral approach of the path by adding a contribution from any possible background of the system that begins in A and ends in B. Therefore, an integral direction is frequently referred to as a 'sum over history' for this reason. Contributions from similar histories are canceled in the total for large systems, and only one history is relevant. The history that classical physics would expect is this history.

For mathematical purposes, in a context of four spatial dimensions instead of three spatial dimensions and a one-time dimension, path integrals are formulated. There is a technique known as 'analytical continuation' that can be used in terms of three spatial dimensions and a one-time dimension to translate results represented in terms of four spatial dimensions into results. This transforms one of the spatial dimensions into the time dimension efficiently. This spatial dimension is often referred to as 'imaginary' time because it requires the use of so-called imaginary numbers used by electrical engineers every day, which are well-defined mathematical artifacts.

The achievement of path integrals in the explanation of non-gravitational physics inevitably led to attempts to use path integrals to explain gravity. Gravity is somewhat different from other physical forces whose classical definition requires fields propagating in spacetime (e.g., electric or magnetic fields). General relativity provides the classical definition of gravity, which states that the gravitational force is related to the curvature of spacetime itself, that is, to its geometry. Spacetime, unlike non-gravitational physics, is not only the arena where physical processes take place, but it is a complex

field. Therefore, a sum over gravitational field histories in quantum gravity is simply a sum over potential spacetime geometries.

The geometry of the three spatial scopes at that time defines the gravitational field at a fixed time. The four-dimensional spacetime that these 3 spatial dimensions sweep out of time represents the history of the gravitational field. Therefore, over all four-dimensional spacetime geometries that interpolate between the initial and final three-dimensional geometries, the path integral is a number. In other words, it is a sum of two three-dimensional limits on all four-dimensional spacetimes that fit the initial and final conditions. Again, mathematical subtleties require that instead of three spatial magnitudes and a one-time dimension, the path integral be formulated in four spatial dimensions.

Issues

There are several mathematical issues with the pathway integral formulation of quantum gravity. How it applies to more recent attempts at building a quantum gravity theory such as string/M-theory is also not obvious. It can, however, be used to correctly measure quantities that can be measured separately in other ways, such as a black hole and entropy temperatures.

No Boundary Proposal

A potential solution to this question is quantum cosmology. In 1983, Stephen Hawking and James Hartle established the 'No Boundary Proposal' theory of quantum cosmology. Recall that the integral path contains a sum of four-dimensional geometries that match the initial and final three geometries with boundaries. The Hartle-Hawking idea is simply to delete the original geometry of three, i.e., to provide only four-dimensional geometries that fit the final geometry of three. The integral path is interpreted as giving the possibility of constructing a Universe from nothing with certain properties (i.e., those of the geometry of boundary three).

Instantons

In fact, it is tremendously difficult to determine probabilities in quantum cosmology using the complete path integral, and an approximation must be used. Because its legitimacy lies somewhere between that of classical and

quantum physics, this is known as the semiclassical approximation. In the semi-classical method, one claims that most of the four-dimensional geometries that exist in the integral path would make minor contributions to the integral path and can therefore be ignored. By only considering a few geometries that give an especially large contribution, the path integral can be determined. They are referred to as instantons. For all boundary three geometry options, instantons do not exist; but those three geometries that admit the presence of instantons are more likely than those that do not. Therefore, the focus is typically limited to three closely related geometries.

You should recall that the path integral is a sum of four spatial dimensions over geometries. Therefore, an instanton has 4 spatial dimensions and a boundary matching the three geometries we want to measure the likelihood of. With the three geometries splitting the sphere in half, modern instantons mimic (four-dimensional) surfaces of spheres. They can be used to measure the quantum phase of the formation of the universe, which can not be defined using general classical relativity. Typically, they exist only in three small geometries, referring to the existence of a tiny universe. Notice that in this process, the idea of time does not emerge. The creation of the universe is not something that takes place within some wider arena of spacetime - the instant represents the accidental emergence of a universe from practically nothing. Quantum cosmology can be said to be approximated by general relativity until the Universe exists, such that time appears.

Types of Instantons

People have found various kinds of instantons that are able to provide practical worlds with the initial conditions. Stephen Hawking and Ian Moss made the first attempt to find an instant that defines the formation of a world within the sense of the 'no boundary' proposition. The Hawking-Moss instant describes the existence of a universe with 'closed' spatial three-geometries that are eternally inflating.

Whether our Universe includes closed, flat or open three-geometry spatial geometries is currently an unanswered issue. The large-scale spatial geometry of a flat universe looks like the ordinary three-dimensional space around us that we encounter. The spatial parts of a rational closed Universe, in comparison to this, will look like a very large but finite radius of three-

dimensional (surface) spheres. It will appear like an infinite hyperboloid in open geometry. Thus, only a closed universe can be finite. However, there is clear evidence nowadays from cosmological studies in support of an infinite open universe. Therefore, it is a significant question whether instantons exist that explain the development of open universes.

Coleman-De Luccia Instanton

The theory behind the instant Coleman-De Luccia, discovered in 1987, is that the matter is initially in a state identified as a false vacuum in the Early Universe. A false vacuum is a typically stable excited state that is mechanically unstable as a quantum. Matter in a false vacuum will 'tunnel' to its true vacuum state in quantum theory. Coleman and De Luccia identified the quantum tunneling of matter in the early universe. They showed that, through the nucleation of bubbles in the false vacuum, false vacuum decay continues. The matter has tunneled within each bubble. Surprisingly, the inside of such a bubble is an infinitely open universe in which there could be inflation. The cosmological instant describing the formation through this bubble nucleation of an open universe is known as an instant of Coleman-De Luccia.

Note that the presence of a false vacuum in the early Universe includes this scenario for the matter. Moreover, once the Universe has been established, the requirement for inflation to occur strongly restricts the way in which matter decays to its true vacuum. Therefore, in the absence of any clarification of these particular pre-inflationary initial circumstances, the existence of open inflating worlds tends to be somewhat imagined.

Hawking-Turok Instanton

A bold approach to this issue has been suggested by Stephen Hawking and Neil Turok. Similar to the instantons of Coleman and De Luccia, they constructed a class of instantons that give rise to open universes. They did not, however, include the presence of a false vacuum or other very particular properties of the state of the excited matter. The cost they pay for this is that there are singularities in their instantons: positions where the curvature becomes infinite. This is a somewhat controversial aspect of their work, as singularities are generally seen as places where the concept breaks down and

must be substituted by a more basic theory.

The question, of course, arises as to which of these instantons correctly defines the existence of our own universe. Through considering quantum fluctuations of these instantons, the way one might expect to differentiate between various theories of quantum cosmology is. In quantum mechanics, the Heisenberg uncertainty principle means that in any quantum theory, vacuum fluctuations are present. Therefore, an instanton provides us with only a background geometry in the integral direction in the complete quantum picture with respect to which quantum fluctuations need to be considered.

These quantum mechanical vacuum fluctuations are intensified during inflation, and they are expanded to macroscopic length scales because of the accelerating expansion of the Universe. Later on, they seed the development of large-scale structures (e.g., galaxies) like those we see today as the Universe has cooled. One sees the imprint of these primordial variations in the cosmic microwave background radiation as minor temperature disturbances.

M-theory, the Theory Formerly Known as Strings

The Standard Model

Particles are known to be points traveling across space in the standard model of particle physics, tracing out a path called the World Line. It is important to provide particles with more degrees of freedom than just their position and velocity, such as mass, electrical charge, color (which is the "charge" associated with a strong interaction) or spin, to take account of the various interactions found in Nature.

In a system known as Quantum Field Theory (QFT), the standard model was developed, which gives us the tools to construct theories compatible with both quantum mechanics and the special theory of relativity. Theories were developed with these methods that explain three of the four known interactions in Nature with great success: electromagnetism and the nuclear forces of Strong and Weak. In addition, a very good convergence was achieved (Electroweak Theory) between Electromagnetism and the Weak Force, and promising proposals were put forward to try to include the Strong

Force. But, sadly, the fourth interaction, gravity, which Einstein's General Relativity (GR) brilliantly explains, does not seem to fit into this system. Whenever one attempts to apply the QFT rules to GR, results that make no sense are obtained. For example, in order to get scientifically sensible results, the force between two gravitons (the particles that mediate gravitational interactions) becomes infinite and we don't know how to get rid of these infinities.

String Theory

The multitude of particle types in String Theory are substituted by a single basic building block, a 'string'. These strings, like loops, can be closed, or open, like hair. It traces a tube or a sheet as the string passes through time, depending on whether it is closed or open. In addition, the string is free to vibrate, and the various particle types are represented by different vibrational modes of the string since different modes are seen as different masses or spins.

One vibration mode, or 'note,' makes the string look like an electron, another like a photon. The graviton, the particle transporting the force of gravity, is also represented in a mode, which is an important explanation for why String Theory has received so much attention. The argument is that in string theory, we can make sense of the interaction of two gravitons in a way we couldn't in QFT. There's no infinity! And it's not gravity that we bring in by hand. In the theory of strings, it must be there. So, String Theory's first great accomplishment was to offer a coherent quantum gravity theory that resembles GR at macroscopic distances. In addition, to explain the other interactions, String Theory also has the requisite levels of independence! A great hope was produced at this stage that String Theory could unify all the known forces and particles together into a single 'Theory of All'.

From Strings to Superstrings

The particles recognized in nature are categorized into bosons (integer spin) or fermions according to their spin (odd half integer spin). For e.g., the former is those that carry forces, the photon that carries the electromagnetic force, the gluon that carries nuclear force, and the graviton that carries gravitational force. The above, like the electron or the quark, make up the

matter from which we are created. The original String Theory defined only boson particles and was thus the Bosonic String Theory. Fermione did not identify it. So, quarks and electrons were not used in Bosonic String Theory, for example.

We can obtain a new theory by applying Supersymmetry to the Bosonic String Theory that explains both the powers and the matter that make up the Universe. This is the superstring theory. There are three distinct superstring theories that make sense, i.e., no mathematical contradictions are shown. In two of them, a closed string is the fundamental object, while in the third, the building blocks are open strings. In addition, we can construct two other consistent string theories, heterotic string theories, by combining the best characteristics of the bosonic string and the superstring.

This proliferation of string theories, however, was a puzzle: If we are looking for the theory of anything, it is an embarrassment of riches to have five of them! Luckily, M-theory came to save us.

M-theory

There was another challenge in researching these theories, aside from the fact that there are five distinct, safe string theories instead of one (three superstrings and two heterotic strings): we did not have resources to explore the theory over all possible parameter values in the theory. Each theory was like a big world, in which only a tiny island was known to us somewhere on the planet. But techniques have been developed over the last four years to explore hypotheses more extensively, i.e., to fly across the sea on each of those planets and locate new islands. And it was only then that it was realized that these five string theories are simply islands, not different, on the same planet! There is an overarching theory, therefore, of which all string theories are just distinct components. This was known as the M-theory. The M could reflect the mother of all theories or mysteries since the planet we call M-theory is still largely unexplored.

The planet analogy of M-Theory is useful for understanding the relationship between the different forms of string theory and M-Theory

In M-theory, a third option still remains for the M. A theory that exists not in 10 but in 11 dimensions refers to one of the islands that was discovered on

the M-theory world. This seems to tell us that M-theory can be seen as an 11-dimensional theory that, at certain points in its parameter space, looks 10-dimensional. Such a theory may have a membrane, as opposed to a string, as a fundamental object. Like a drinking straw seen from a distance, when we curl the 11th dimension into a small circle, the membranes will look like strings.

Black Holes in M-theory

Black Holes have been studied in General Relativity for several years as configurations of spacetime, leading to very large gravitational fields. But because we cannot construct a coherent GR quantum theory, some puzzles about the microscopic physics of black holes have been posed. One of the most interesting was connected to the Black Holes entropy. Entropy is the quantity in thermodynamics that measures the number of states of a system that look the same. There is a great entropy in a very untidy space, as one can transfer something on the floor from one side of the room to the other, and because of the mess, no one can know - they are equivalent states. In a very tidy room, it will be obvious if you change something, because everything has a place of its own. So, we equate chaos with entropy. The Black Holes are suffering from a massive disease. No one understood, however, what the states connected to the black hole's entropy were. In this place, the last four years have brought great excitement. Similar techniques to those used to find the M-theory islands allowed us to explain exactly what states correspond to the disorder of certain black holes, and to explain the thermodynamic properties that had previously been deduced using less direct arguments using fundamental theory.

THEORY OF LIGHT AND WAVES

Observing the interaction of atoms with various forms of radiant, or transmitted, energy, such as the energy associated with visible light that we detect with our eyes, infrared radiation that we feel as heat, ultraviolet light that causes sunburn, and x-rays that produce images of our teeth or bones, scientists discovered much of what we know about the structure of the atom. You should be familiar with all of these types of radiant energy. We begin our explanation of how our current atomic model came to be by outlining the properties of waves and the different types of electromagnetic radiation.

Figure 1.1.1 When a drop of water falls over a smooth water surface, it causes a series of waves that flow outward in a circular pattern.

Properties of Waves

A wave is an energy-transmitting periodic oscillation that travels over space. Anyone who has been to a beach or thrown a stone into a puddle has seen

waves moving through the water (Figure 1.1.1). These waves are created when energy is transferred to the water by wind, a stone, or another disturbance, such as a passing boat, causing the surface to oscillate up and down as the energy moves outward from its source. When a wave passes over a certain spot on the water's surface, anything floating there slides up and down.

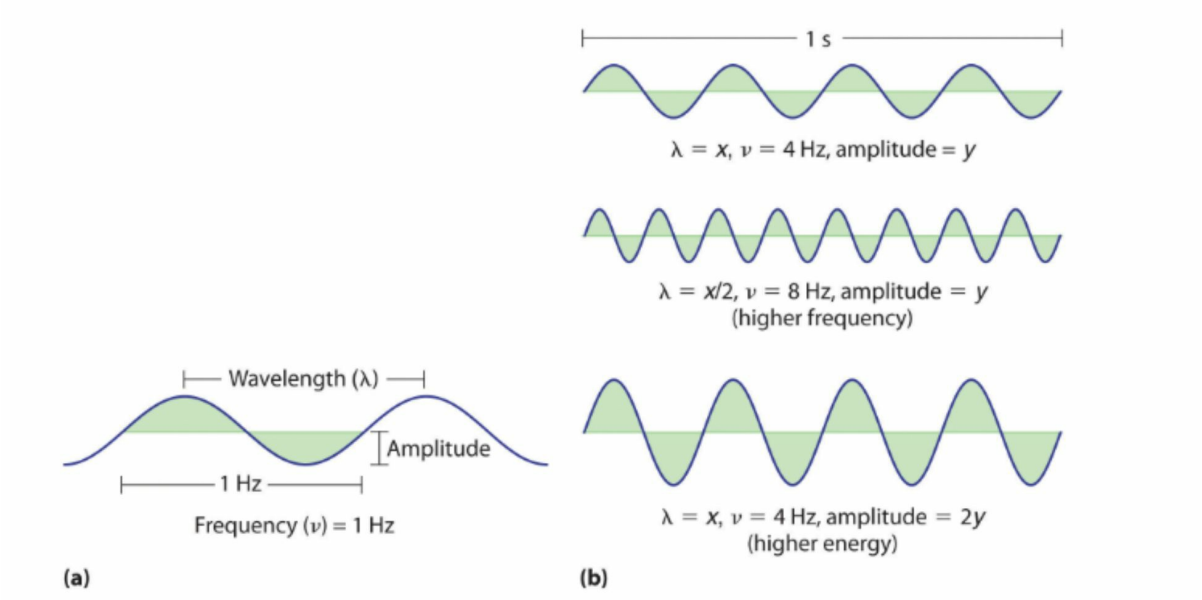

Wavelength (λ)
Amplitude
1 Hz
Frequency (ν) = 1 Hz
(a)
1 s
λ = x, ν = 4 Hz, amplitude = y
λ = x/2, ν = 8 Hz, amplitude = y
(higher frequency)
λ = x, ν = 4 Hz, amplitude = 2y
(higher energy)
(b)

Figure 1.1.2: Wavelength (in meters), frequency (v, in Hz), and amplitude are all shown on this diagram of a wave. (b) In terms of wavelengths per unit time, the wave with the shortest wavelength has the most (i.e., the highest frequency). The one with the larger amplitude has more energy when two waves have the same frequency and speed but different amplitudes.

Waves have distinct characteristics (Figure 1.1.2). Waves are periodic, as seen in Figure 1.1.1, in that they repeat themselves in both space and time. The wavelength (), or distance between two corresponding points in a wave—for example, the midpoints of two peaks or two troughs—is the distance between two corresponding points in a wave—for example, the midpoints of two peaks or two troughs. λ stands for lowercase Greek nu, and lambda stands for lowercase Greek lambda. The number of oscillations (i.e., waves) that pass over a given place in a given period of time is called frequency (v). The period of a wave is the number of oscillations that pass through a specific location in a given amount of time. The most common units are oscillations per second (1/s = s1), often known as the hertz in the SI system

(Hz). Heinrich Hertz (1857–1894), a pioneer in the science of electromagnetic radiation, was the inspiration for the name. The amplitude (the vertical height of a wave, which is defined as half the peak-to-trough height), or vertical height of a wave, is defined as half the peak-to-trough height; as the amplitude of a wave with a given frequency increases, so does its energy. As you can see in Figure 1.1.2, two waves can have the same amplitude but different wavelengths and vice versa. The distance traveled per unit time, which is generally measured in meters per second (m/s), is the speed (v) of a wave. The product of a wave's wavelength and frequency determines its speed:

$$(\text{wavelength})(\text{frequency}) = \text{speed}$$

$$\lambda\nu = v$$

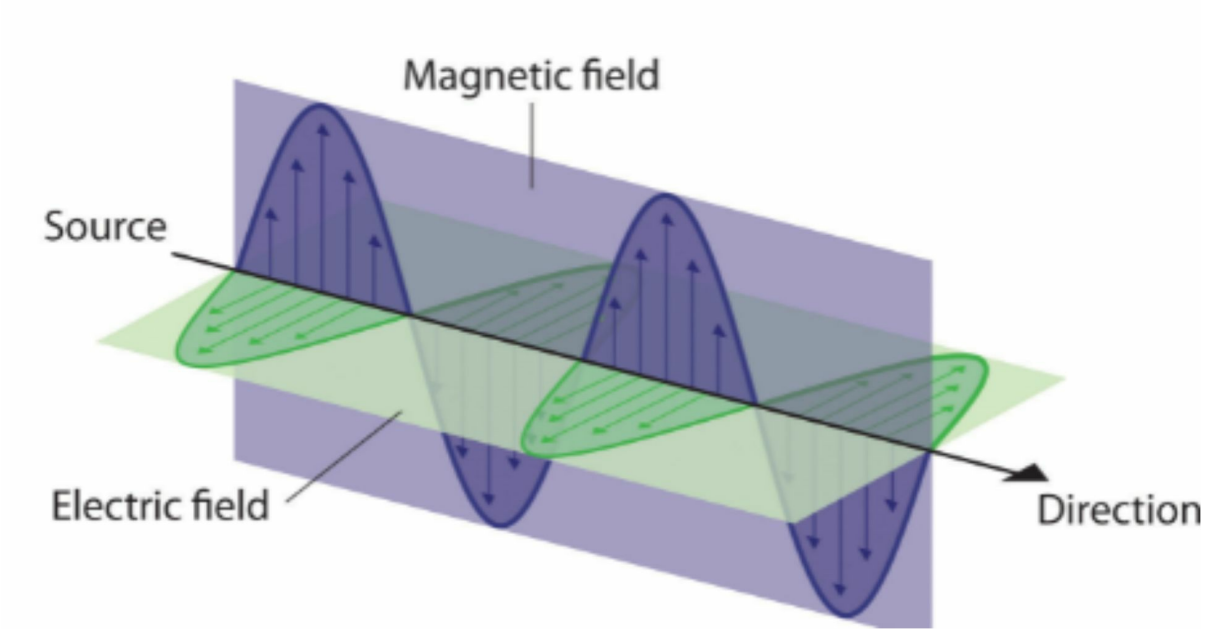
$$\left(\frac{meters}{\cancel{wave}}\right)\left(\frac{\cancel{wave}}{second}\right) = \frac{meters}{second}$$

Make sure you don't mix up the symbols for speed (v) and frequency (v). Water waves are slower than sound waves and can pass through solids, liquids, and gases. While water waves travel at a few meters per second, sound travels about 343.5 meters per second in dry air at 20 degrees Celsius. Ultrasonic waves are used in a range of applications, including underwater item identification and internal organ imaging because they travel at a quicker speed (>1500 m/s) and have a higher frequency.

Electromagnetic Radiation

The cyclic oscillation of materials in water waves transmits energy through space (the water). Electromagnetic radiation, on the other hand, is energy that is transmitted or radiated through space in the form of periodic oscillations of electric and magnetic fields, which is energy that is transmitted or radiated

through space in the form of periodic oscillations of electric and magnetic fields. (See Illustration 1.1.3). Figure 1.1.4 depicts some types of electromagnetic radiation. In a vacuum, all kinds of electromagnetic radiation —whether microwaves, visible light, or gamma rays—travel at the speed of light (c), a fundamental physical constant with a value of 2.99792458 108 m/s (about 3.00 108 m/s or 1.86 105 mi/s). This is a million times quicker than the sound speed.



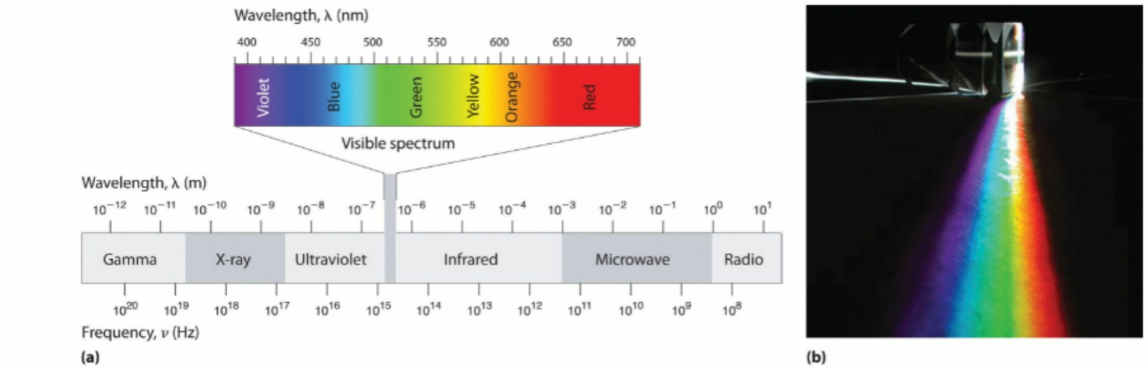
The Nature of Electromagnetic Radiation (Figure 1.1.3). Perpendicular oscillating electric and magnetic fields make up all forms of electromagnetic radiation.

Because all types of electromagnetic radiation have the same speed (c), the only thing that distinguishes them is their wavelength and frequency. As shown in Figure 1.1.4 and Table 1.1.1, the wavelengths of common electromagnetic radiation range from 101 m for radio waves to 1012 m for gamma rays emitted by nuclear processes. We can establish that the frequency of electromagnetic radiation is inversely related to its wavelength by replacing v with c in Equation 6.1.1:

$$c = \lambda\nu$$

$$\nu = \frac{c}{\lambda}$$

Radio waves, for example, have a frequency of around 108 Hz, whereas gamma rays have a frequency of around 1020 Hz. The wavelengths of visible light, which is electromagnetic radiation detectable by the human eye, range from roughly 7 107 m (700 nm, or 4.3 1014 Hz) to 4 107 m (400 nm, or 7.5 1014 Hz). It's worth noting that when the frequency rises, wavelength falls, whereas c, as a constant, remains constant. In the same way, as frequency lowers, the wavelength lengthens.



The Electromagnetic Spectrum (Figure 1.1.4). (a) The wavelength and frequency ranges of electromagnetic radiation are depicted in this diagram. The visible part of the electromagnetic spectrum is a limited band of wavelengths between 400 and 700 nanometers. (b) White light is split into several wavelengths when it passes through a prism, each of which corresponds to a different hue in the visible spectrum.

Within this visible range, our eyes detect various wavelengths (or

frequencies) of radiation as the light of various colors, ranging from red to violet, in decreasing wavelength order. A prism can separate the components of white light, which is a blend of all visible light frequencies, as illustrated in portion (b) of Figure 1.1.4. A rainbow is created by a similar occurrence in which water droplets hanging in the air function as tiny prisms.

Table 1.1.1: Common Wavelength Units for Electromagnetic Radiation

Unit	Symbol	Wavelength (m)	Type of Radiation
picometer	pm	10^{-12}	gamma ray
angstrom	Å	10^{-10}	x-ray
nanometer	nm	10^{-9}	x-ray
micrometer	µm	10^{-6}	infrared
millimeter	mm	10^{-3}	infrared
centimeter	cm	10^{-2}	microwave
meter	m	10^{0}	radio

The energy of electromagnetic radiation is exactly proportional to its frequency and inversely proportional to its wavelength, as you will see shortly:

$$E \propto \nu$$

$$E \propto \frac{1}{\lambda}$$

Unlike visible light, which is largely innocuous to our skin, UV radiation, which has wavelengths of less than 400 nm, has enough energy to cause serious skin damage in the form of sunburn. By absorbing sunlight with wavelengths less than 350 nm, the ozone layer protects us from the detrimental effects of extremely powerful UV radiation.

The energy of electromagnetic radiation rises as the frequency and wavelength decrease.

ELECTROMAGNETIC THEORY

Electromagnetic theory is an area of physical science that studies this interaction of electromagnetic fields and all objects are made up of charged particles which creates the electromagnetic field. The study of electromagnetic phenomena requires knowledge from mathematics, physics, chemistry and engineering as well as being highly interdisciplinary in nature.

Over time these concepts have been developed into a framework for understanding many natural phenomena such as lightning storms or radio waves and have been adapted to other areas such as communications technology like microwaves or cell phones.

The earliest theory used to describe electromagnetism was developed by Faraday in the 1830s. It was based on his analysis of magnetic induction, and he developed a theory involving lines of flux that is now called classical electromagnetism. Today it is known as classical electromagnetism. This early theory does not consider the electric charge or specific charges and only describes what happens when an electric field exists around any given point in space.

Electromagnetic waves are created when an object, such as a charged particle with a mass much smaller than the earth, moves through an electromagnetic field. These move through an electric field and a magnetic field in a transverse direction. The electric field causes the charged particle to move in the direction of the field, but has a small energy change called an oscillation. The magnetic field is responsible for keeping this scalar wave around the particle as it moves forward and also keeps it in a current form. If a material object is moved through space perpendicular to both of these two fields, there will be no effect because they cancel each other out.

We can start our journey in quantum physics from Robert Hooke, an English scientist, architect, and polymath who lived between the 17th and 18th centuries.

Mr. Hooke was the first, using a microscope, to visualize a

microorganism.

He also wrote the famous book Micrographia (1665) and, trying to explain the origin of colors, developed his “pulse-theory.”

In Micrographia, he had noted the colored rings in thin transparent films and interpreted them in terms of vibrating pulses of light. He also theorized that the vibrations were perpendicular to the propagation direction and that the waves were similar to those produced by a stone thrown in water. Hooke’s analysis of color was in the Aristotelian modificationist tradition: All colors were a modification of white light. In the case of thin films, the colors were a consequence of ‘confusions’ in the reflections and refractions of white light. Nonetheless, Hooke’s pulse theory of light, and his belief in the universal nature of vibrations, is considered a precursor of wave theories.

Subsequently, Christiaan Huygens, a Dutch physicist, mathematician, and astronomer, developed a mathematical wave theory of light (1678) on a theory that was representing light as waves.

In his book, Treatise on light, he proposed that light was emitted in all directions as a series of waves in a medium called Luminiferous ether. He and Newton could only envision light waves as being longitudinal, propagating like sound and other mechanical waves. Also, since waves are not affected by gravity, he assumed that light slows down upon entering a denser medium.

Let's jump forward a century to introduce Thomas Young, a brilliant British polymath that made numerous contributions to the fields of light, vision, energy, solid mechanics, and Egyptology.

In Young’s judgment, of his many achievements, the most important was to establish the wave theory of light. Young worked openly in contrast with Newton’s century-old view, expressed in his opera, Opticks, that light behaves like particles.

Young embraced the wave theory of light and developed various demonstrations to support this viewpoint.

The most famous of these demonstrations was the young’s interference experiment, which is considered the predecessor of the double-slit

experiment.

The double-slit experiment (illustrated in Fig.1) was one of the key ways physicists showed that light can behave like a wave. When you shoot rays of light through two slits, they interfere with each other like waves, creating a certain predictable pattern on a screen placed behind the slits. This is known as a diffraction pattern.

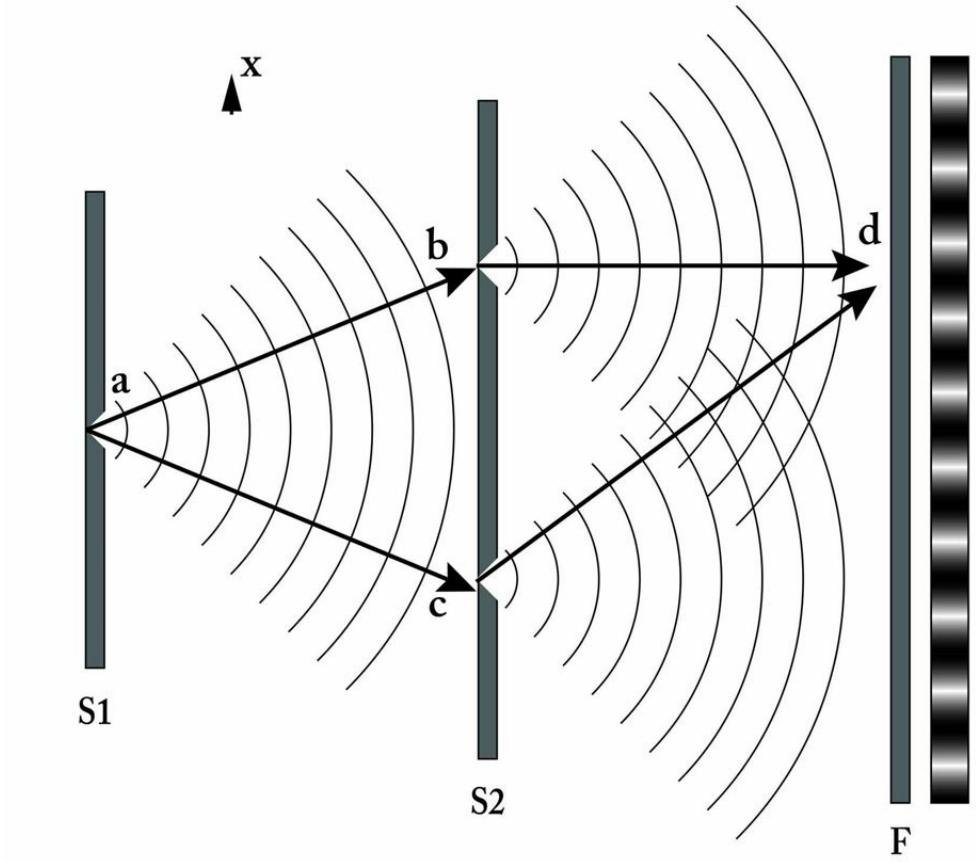


Fig.1 - The double-slit experiment

The light corpuscular theory (1637) states that light is made up of small discrete particles that travel in a straight line with a finite velocity and possess impetus. This theory was in direct conflict with wave theory and was (temporarily) set aside.

In 1845, just 170 years ago, Faraday discovered that a magnetic field

influenced polarized light. This phenomenon is known as the Faraday Effect or the magneto-optical effect. Thanks to this discovery, for the first time, scientists started to relate light with electromagnetism. The following year, in May 1846, Faraday published the article Thoughts on Ray Vibrations, in which he speculated that light could be a vibration of the electric and magnetic lines of force.

Michael Faraday, through his experiments, showed how a changing magnetic field induces an electromotive force (EMF), resulting in an electric current. He also found that electric fields sometimes act like magnetic fields and developed equations to calculate the forces exerted by both.

James Maxwell, a Scottish physicist, was one of the very few scientists who paid attention to Faraday's idea. For a young researcher, it was a risky move, but he believed it was one of the missing parts in understanding not only magnetism but also the fundamental nature of light. Maxwell started to work on a set of equations that held true for all electromagnetic interactions. In the process of developing his all-encompassing equations, Maxwell predicted the existence of electromagnetic waves.

Maxwell's first and second equations are a form of Gauss's Law, but the most interesting for us is Maxwell's third equation.

This last equation is based on Faraday's work. Starting from Faraday's law of induction that says that a changing magnetic field will induce an electromotive force in a loop of wire, Maxwell developed a more general law that shows the value of that induced EMF.

Maxwell's third law states that the EMF is equal to the line integral of the electric field over a closed loop.

$$\int \vec{E} \cdot \vec{ds} = - \frac{d\Phi}{dt}$$

Where:

$\vec{E}$ = Electric field

$\vec{ds}$ = Infinitesimal element of closed loop

$d\Phi$ = Change in magnetic flux

dt = Change in time

This equation highlights the connection between a changing magnetic flux and an induced electric field.

On differentiating his partial differential equations, Maxwell obtained mathematical wave equations. Maxwell was then able to mathematically prove that electromagnetic signals are not transmitted instantaneously but are communicated through space as waves, but there is more!

He was able to prove that these mathematical wireless electromagnetic waves traveled at the same speed as light. This prompted his characteristically modest understatement:

[…] Light itself (including radiant heat and other radiations, if any) appears to be an electromagnetic disturbance in the form of waves carried through the electromagnetic field according to electromagnetic rules (1865).

In one bold leap, he had united not simply electricity and magnetism, but also light, heat, and “others radiations, if any.”

This was an incredible progress for the field at that time, but Maxwell didn’t consider the Ultraviolet catastrophe.

QUANTUM ENTANGLEMENT

Firstly, there are still tons of mysteries left in the universe despite scientific advances. Awe breeds mystery, and awe is good for the soul. Overestimating our superiority will bring forth self-fulfilling desires, which can lead to pride and ruin

The Concept of Quantum Entanglement

Schrödinger presented in 1935 and 1936 a two-part paper in the Cambridge Philosophical Society's proceedings in which he discussed and expanded the theories of Einstein, Podolsky, and Rosen. The Einstein-Podolsky-Rosen (EPR) claim was the culmination in certain respects of Einstein's criticism of quantum mechanics orthodox Copenhagen and was intended to prove that the theory was incomplete. The condition of a system in classical mechanics is simply a definition of the system properties — more precisely, it is the definition of a number of parameters from which the description of characteristics may be reconstructed: the positions and moments of all particles comprise: The theory dynamics describe how properties change for the state in terms of an evolution law. Wolfgang Pauli defined physical processes as a 'detached observer' idealization, in a letter to Max Born (see The Born-Einstein Correspondence, Born, 1992; p. 218.) For quantum structures, such a definition is not feasible in the Copenhagen understanding. Rather, the quantity status of a system should be interpreted as a record of what an observer has done to and observed in the system, and the value of the condition lies in the probability of the result of possible system observations (theory.) Einstein dismissed this point of view and brought forward a number of reasons to show that a quantum system is merely an imperfect definition. Sometimes the missing parameters are referred to as 'hidden parameters' or 'hidden variables.'

It should not be believed that Einstein's notion of a total theory includes deterministic theory. He needed very certain conditions of separability and position for composite structures composed of different components: each component system should have its own properties independently (as Einstein said – 'so-sein'), and the characteristics of a distant system should not be

changed instantly (or the probability of such pro-systems) Earlier experiments, especially in Bell's case for the non-location of quantum correlations, showed that these requirements, suitably conceived as restriction of probability, correlate with the criterion that statistical correlations between different processes can be reduced to probability distributions in the context of Reichenbach for specific causes (deterministic or stochastic.

Two particles are prepared from the source of the original EPR particle in a certain 'normal' quantum state of the composite system (a condition which is not expressible as a combination of the probability of propagation of certain normal quantal states and cannot be reduced independently by a pure quantal state of each particle.) When particles are separated, 'matching' associations are made between the positions of the two components and their momentum: any position or momentum measurement on one individual particle would allow the outcome of any position measurement or dynamic measurement on the other particle to be determined with certainty. Both measures are mutually exclusive: either position measurement or momentum measurement may be carried out at once, but not at the same time. After the calculation of the momentum, for example, after the correlation of the position, the moments of the two particles do not show any correlation.

The position estimation disturbs the connection between complex values and vice versa. Beyond this function, where all correlations can be found, but not all for the same pair of quantum particles, quantum particles position and momentum correlations are exactly like traditional correlations between two billiard balls following a collision. The EPR point is that quantum mechanics is incomplete because the common causes, or elements of reality, are not part of the Quantum State Explanation. Classical correlations may be explained by the common cause or associated 'elements of reality.' But since I can foresee either x1x1 or p1p1 without any intervention with device No. 1 as a scholar during a test, it is difficult to say one of the two questions I should bring before: it sounds as though our scholar is prepared to answer the first question he will be asked, regardless. Therefore, he must know all answers; that is impressive knowledge, irrespective of the fact that our scholar is still so depressed or exhausted after his first response that any of the subsequent responses are "wrong."

Schrödinger proved that if two particles are prepared in an EPR quantitatively state with the relationship of two 'canonical conjugates' dynamic quantities (i.e., quantities such as position and momentum, the values of which are necessary to determine all the characteristics of a classical system.) So (Schrödinger, p. 559) Program No. 1 'knows not only these two responses but a great many, at least for whom we do' (Schrödinger, p. 559.) Schrödinger coined the term 'enclosure' as a description of this particular link between quantum systems.

When two systems, of which our respective members are acquainted, communicate briefly because of established influences, and if the systems split again after a time of reciprocal control, they can no longer be as defined as before, i.e., through granting each of them its own leader. I should not consider this one but rather the signature function of quantum mechanics, which enforces the complete deviation from classical thought. Via the interaction, the two members have entangled [the quantum states]. The other way to explain the peculiars is: the best knowledge possible of a whole does not automatically entail the best possible knowledge of all of its elements, even though they are entirely separate and therefore practically able to be 'best understood possible,' that is, any of them having their own representative. The lack of information is by no means due to the insufficiency of the relationship – at least not to the degree that it could be more completely understood – because of the relationship itself.

Recently, it was noted that, while we limit the disconnection to one system, the representative obtained for another system is definitely not independent of the specific choice of observations that we chose for that purpose, and those are, of course, completely subjective. It is quite surprising that the principle would allow a machine to be piloted or guided at the whim of the experimenter in one or other kinds of state, given its lack of exposure to it.

Mr. Schrödinger showed in the second section that an experimenter could 'move' the second apparatus to a chosen mix of quantum states with a rational range of operations conducted by a single member of an interlocked pair, possibly using additional 'ancilla' or supporting particles, with a probability distribution that is based on the inhaling condition. The second system cannot be guided to a particular quantum state on the experimenter's likes, but for

certain copies of the entangled pair, the experimenter will limit the quantum state of the second system to a set of quantum states, where these states coincide with the potential effects of measurements made by the entangled pair systems or by the paired systems. Then, he found it highly troubling that the interplay between two systems happens only at times that are as feasible as possible to disregard the time required by light for journeying between systems and the normal amounts of time linked to other shifts in the composite structure. He hypothesized that the two systems might potentially be in a combined combination of quantum states determined by their entangled state over long distances.

Most physicists offered Einstein's unsuitable "departed observer" view of the physical theory, the puzzling features of entangled quantum states, and saw Bohr's reaction on the EPR (Bohr, 1935) as vindicating the Copenhagen understanding. This was unfortunate, as the theory of interposition was neglected for 30 years until the analysis of the EPR claim by John Bell (Bell, 1964.) Bell has studied the interlocking of two-value functional quantities (for example, polarization or spin) in two different processes in an interlocked state in processes that are simpler than in the EPR case. Bell revealed that the statistical differences between the calculation effects of suitable quantities selected for the two schemes vary from the inconsistency resulting from Einstein's reparability and position assumptions — under the basis that the differences have a common origin. This disparity is now called the disparity of Bell, and various associated disparities can be inferred to be a requisite condition for conventional or popular reasons.

The research by Bell has contributed to a continuing debate regarding the foundations of quantum mechanics. A significant feature of this topic was the clarification that interlocking would last long distances, falsifying the supposition of Schrödinger that interlocking particles spontaneously deteriorate as two different interlocking particles. (The experiments between the Canary Islands in La Palma and Tenerife confirmed the free space interplay of the photons at 143 km. See Herbst et al. 2014.) However, only in the 1980s did Physicists, computer scientists and cryptologists begin to find the non-local interaction between the entangled quantum states as a new kind of non-classical physical tool which they could exploit; See the interactive novel Completely Unexpected, That Nobody Knows Quantum Mechanics (A

Grim Comic on Entanglement), Bub and Bub 2018 for a debate about how to get involved, why it's conceptually mysteries, and what to do about it, including clear proof of Bell's theorem. See "The Pleasure of Entanglement" by Popes cu and Roerich in Lo, Popes cu and Spiller, 1998, Nielsen & Chuang, 2000, and Bub 2016, for further debate on interlocking as a physical property, including the calculation of interlocking and handling and purification of interlocking by local operations.

QUANTUM JUMPS

Atomic electron transition is the change of an electron from one quantum state to another within an atom. This transition appears discontinuous as the electron "jumps" from one energy level (orbital) to another in a few nanoseconds (billionths of a second). In other words, for an extremely small increment of time, that electron popped out of existence and then reappeared in a different location. A tiny bit of matter became nonphysical and then became physical again. This is possible only if a nonphysical reality does in fact exist.

Some scientists are not comfortable with the idea that an electron could pop in and out of existence and so use different terminology. They call an electron "localized" when it can be seen and "non-localized" when it cannot.

Quantum jumps create light. An electron has a natural orbital that it occupies. A pulsation of energy causes that electron to jump to a higher orbital. When the electron drops back to its former orbital, the energy it loses is emitted as a photon (packet of light energy). Each element (in the periodic table) has a unique and steady frequency with which electrons jump back and forth between orbitals giving off light. In other words, each element has a unique frequency with which its electrons pass back and forth between physical and nonphysical states.

Max Planck developed the quantum theory to explain how the vibratory frequency of the electron appeared to be in "chunks" or quanta of energy. Suddenly and without any known cause, an electron would suddenly radiate a quantum of energy as a pulse of light. X-rays and other electromagnetic waves can be given off only in these discrete packets/quanta. Niels Bohr also talked about light being emitted in quantum jumps. [A quantum jump is a change in energy by a single quantum.]

Stephen Hawking has remarked that "quantum fluctuations lead to the creation of tiny universes out of nothing." If we translate "nothing" in this context to mean a nonphysical reality, then Hawking's observation is most fitting. Nothing can create anything, but nonphysical energy can. If the nonphysical is a state of pure primary energy, then it can create not only tiny

universes but also the entire universe. This could be the missing link between quantum theory and the general theory of relativity.

It is helpful to view subatomic particles as fluctuating energy packets in transition from the non-physical into the physical. Sometimes these pre-physical particles may have a position, at others a velocity. When you intend to measure where it is located, the particle co-operates by letting you know exactly where it would be if it became fully physical at that moment. If you intend to measure how fast it is moving, the pre-physical particle lets you know the exact velocity at which it can travel in physicality. In other words, the position and velocity of the pre-physical particle are potentialities rather than actualities—neither of which has any bearing on the final result (the atom), which is always the same regardless of how its internal particles behave.

Connectedness

There are some repeatable phenomena at the quantum level that strongly suggest universal connectedness. Simply stated: any two objects that have ever interacted may be forever connected. The behavior of one instantaneously affects the other and everything connected with it, no matter how far apart they may be, even though there is no physical force connecting the objects in question.

The experimental facts concerning entanglement are convincing evidence of a non-physical reality. The logic is thus: (a) two objects are in fact connected, (b) there is no physical force between these objects, therefore (c) whatever is connecting them must be nonphysical.

The time between the detection of one photon and the detection of its twin is less than the time it takes for light to go from one detection apparatus to the other. Since light is the ultimate limiting velocity in physical reality, whatever communication is happening between the twin particles must be nonphysical—i.e., at the speed of thought.

Suppose twin particles are not directly connected to each other but are two different individuations simultaneously expressing from a common source. With that in mind, try this experiment:

Thought experiment: Imagine you have a laser pointer pen on which is fastened a beam splitter so that it projects two identical dots on a screen. Keeping the dual laser beams pointed at a right angle to the screen, move the pen in whatever manner you wish, at random or tracing geometric patterns. Whichever way you more the laser pen, the two dots move in unison in precisely the same direction at precisely the same time. It would appear as if the two dots were instantaneously communicating with each other, but it was really a single pen projecting the same image in two places simultaneously—making the two dots move in direct response to your intention. Perhaps this is how entanglement works: twin particles are dual projections of the same nonphysical intention.

The speed of thought is instantaneous, infinitely faster than the speed of light. Perhaps the entangled particles are a manifestation of the same thought. Although lacking in consciousness themselves, the particles respond to mental energy that originates from a nonphysical source.

In Two Places at Once

Experiments by Niels Bohr, Erwin Schrödinger, and others show that particles, such as electrons, can be in two places at once and can also behave as a particle in one moment and as a wave in the next, depending on how an observer decides to measure it. These apparent anomalies occur only because the particle in question has no definable state or position until such are measured.

Experimental evidence shows that subatomic particles can at the same time be in two different positions, travel on two different paths, have two different polarities, and/or function as both a particle and a wave. The particle in question is said to be in a superposition state—meaning that it exists in all possible states simultaneously, provided we do not observe or measure it. It is the act of measuring that causes the subatomic particle to express itself through only one of these possibilities.

Existing in all possible states (superposition) happens when the particle is in a pre-physical state capable of taking all possible paths on route to becoming fully physical. When we decide to measure a specific aspect of this pre-physical particle, it takes a specific route into physicality. The superposition

state then collapses because all the other possibilities have been replaced with a single actuality.

It is the experiment that determines which of two possibilities is observed. Your choice of measurement determines whether you see (a) a particle or a wave, (b) a position or a velocity, or (c) one location or the other. As an observer, you do not get to see whatever you wish. Your choice is limited to seeing which of two properties (or locations) a quasi-particle will manifest in as it becomes physical.

According to the Copenhagen interpretation, one could project a single proton in its superposition state into two different boxes. When the boxes remain sealed, the proton would exist as a potentiality in both locations. Then, when the door of one box is opened, the proton appears in that box and the other is empty, regardless of which box is the first to be opened. There is an inconsistency in this theory. It is impossible to project a superposed proton into a box because the moment it hits the exterior surface of the box the proton becomes physical and stops there—just as one can project protons onto a screen but not through a screen.

Some theorists took the idea of an electron or proton appearing in two places simultaneously to the next level to assume that a complete atom (or a whole object) can exist as a combination of multiple states corresponding to different outcomes. This is not possible. An atom (or object) is fully physical and cannot exist in a superposition state (which term applies only to pre-physical possibilities).

Cat-in-the-Box Riddle Solved

Erwin Schrödinger dismissed the false assumptions of the Copenhagen interpretation by showing that its logical consequences are nonsensical. Using this infamous cat-in-the-box thought experiment, Schrödinger demonstrated (tongue-in-cheek) that a cat could simultaneously be both dead and alive.

The imaginary experiment consisted of putting inside each of two sealed boxes: (a) a flask of poison, (b) a tiny bit of radioactive substance so small that one atom of it has a 50:50 chance of decaying within one hour, and (c) a Geiger counter that when it detects decay, triggers a hammer to break the

flask of poison. A cat in its superposition state is projected into both boxes. If no decaying atom is detected in either box, then a live cat will show up in whichever box is opened first, and the other box will be empty. If, however, a decaying atom is detected in one box, the cat in that box will be killed. As long as the boxes remain sealed, the same cat will be alive in one box and dead in the other.

There are two fallacies upon which the cat-in-the-box "reductio ad absurdum" experiment depends:

Because cats are physical objects, they do not have superposition states and cannot be projected into multiple locations. A cat can exist in only one location at any given time. Similarly, a proton in a superposition state cannot be projected into even one box because its superposition state collapses the moment it hits the box.

Mutually exclusive conditions cannot exist in superposition states (e.g., a particle cannot be a proton at one location and not a proton at another). A cat cannot simultaneously be a cat (alive) and not a cat (dead).

Observation

Experimental evidence suggests that an observer may influence the behavior of subatomic particles. This is not entirely accurate. It is the choice of experimental method that determines whether one sees a particle or a wave, a particle's position rather than its velocity, a particle in two places rather than one, or a particle that has had one history rather than another. The observer chooses his experience of reality, but not reality itself. An atom is an atom, and the moon is the moon, whether they are being observed or not.

If a physical property of an object can be known without it is being observed, then that property could not have been created by observation. It must have existed as a physical reality before its observation. The early universe existed long before there were any witnesses to observe it.

The choice of experiment affects what is observed only because subatomic space is a transitional state in which nonphysical energy is in the process of becoming physical. It can do so in multiple ways, and it does not matter to the result (the fully physical atom) which interim path is chosen. If an

observer wishes to see a specific aspect of the transition, nonphysical reality obliges.

Human observers have thoughts—and thoughts, being nonphysical, are communicated instantaneously. By structuring an experiment in a specific way, the observer instantly makes his intention known to the nonphysical source of the single or twin particles, which source co-operates with the experiment. Whereas the energetic phenomenon in question is always there, it is not always in the same presentation.

A photon duplicates its twin's behavior instantly. Because there is no time-lapse, information can't be communicated between the particles by any physical means. Whatever is going on for the particle and/or its twin exists independently of anyone's observation of it or them. This meets Einstein's criterion that the moon is still there when we are not looking at it.

THE DIFFERENCE BETWEEN CLASSICAL AND QUANTUM PHYSICS AND THE DUALITY OF WAVES AND PARTICLES

Classical physics is fundamental; knowing the whole thing about the past aids you in anticipating the future. Correspondingly, having full information of the future allows for precise computation of the past.

In quantum mechanics, objects are neither particles nor waves; they are anything in between. The matter is a curious combination of the two. We can only make likely estimates of the future if we have full information about the past.

Two grenades with similar fuses will blow at an identical time in classical physics. Two indistinguishable radioactive atoms can and will generally blast at very dissimilar times, as per quantum physics. Despite the statistics, two indistinguishable uranium-238 atoms will experience radioactive decay detached by billions of years.

Physicists also utilize a law to differentiate between classical and quantum physics. It is quantum physics if Planck's constant gives the idea in the equations. It is classical physics if it does not.

Even though many characteristics endure to be discovered, most physicists agree that quantum physics is the accurate theory. In the circumstance where the quantum properties are undisclosed, classical physics can be inferred from quantum physics. The correspondence theory refers to this truth.

Quantum physics is the newest science that has substituted classical physics. We have the Newtonian image of a clockwork world on the one side. All of corporeal life is an enormous machine that impulses forward in time, altering its conformation, probably according to deterministic rules. Newton imagined his god as an arithmetician who formed the universe out of physical

rudiments and set them in motion using a few rudimentary mathematical rubrics. These rubrics are mainly accountable for all of nature’s vagueness and multiplicity. Similarly, all mechanisms, no matter how complex, can be elucidated using these basic rules.

On the other side, there is the quantum universe, which seems more like a slot machine than a clock from our viewing platform. We see the equipment in the quantum world as probabilistic.

The quantum uprising, in reality, goes far outside, just integrating probability as an important function. It substitutes the Newtonian clock with an alien system based on much more progressive mathematics. The quantum revolution shows that the classical view is mistaken.

Waves and Particles

In quantum physics, wave-particles duality states that every quantum phenomenon or particle may be represented as either wave or particle. It reflects the inadequacy of classical terms like "particle" and "wave" to properly explain quantum-scale things' behavior.

As Albert Einstein put it, "it seems as though we must employ one theory occasionally and the other theory at other times, but at other times we may use either." We are confronted with a new kind of challenge. We have two conflicting visions of reality; none of them completely explains the phenomenon of light when seen individually, but when viewed together, they do.

The recent scientific theory maintains that all particles have a wave nature and vice versa, according to the work of Albert Einstein, Max Planck, Louis de Broglie, Niels Bohr, Arthur Compton, and others.

This behavior has been seen not just in elementary particles but also in complex particles like molecules and atoms. Wave characteristics are typically not detectable for the macroscopic particles due to the very short wavelengths.

Although the wave-particle duality has proven useful in physics, its meaning or interpretation has yet to be determined; see Quantum Mechanics Interpretations.

The "duality dilemma" was viewed by Bohr as a basic or philosophical feature of nature. In various physical conditions, a particular kind of quantum item will show wave, particle, or both characteristics. He viewed such duality as one facet of the complementarity idea. The quantum mechanical explanation, according to Bohr, requires abandonment of the cause & effect relations, or the complementarity, of space-time images.

Werner Heisenberg pondered the issue more deeply. He viewed duality as existing in all quantic entities, but not exactly in the way that Bohr understood quantum mechanics.

He noticed it through a process known as second quantization, which creates a completely new notion of fields that exist in conventional space-time while yet allowing causality to be seen.

Classical field values (such as Maxwell's electric and magnetic field strengths) are replaced by a whole new kind of field value in quantum field theory. Ordinary quantum mechanics may be derived as a specific consequence of quantum field theory if the logic is reversed.

Black-body Radiation and Planck's Law

Max Planck presented a study in 1901 that successfully replicated the spectrum of light produced by a burning item. To do so, Planck had to make a mathematical assumption about the oscillators' quantized energy, i.e., the atoms of the black body that produce radiation. Later, Einstein argued that electromagnetic radiation, not the energy of emitting atoms, is quantized.

Classical reasoning could not explain black-body radiation, which is the emission of electromagnetic energy as a result of an object's heat. The equipartition theorem of classical mechanics, which is the foundation of all classical thermodynamic theories, states that an object's energy is equally distributed across its vibrational modes.

However, applying the same logic to a hot object's electromagnetic emission was not as effective. It has long been known that heated things produce light. Because light is known to be waves of electromagnetic, physicists intended to use classical principles to explain its emission.

The black body issue arose as a result of this. Because the equipartition

theorem described the vibrational modes of the thermal item so accurately, it was only reasonable to infer that it would describe the radiative emission of similar things as well.

However, if each mode was given an equal share of energy, the short-wavelength modes would rapidly consume all of it. When the Rayleigh-Jeans law was plotted, it was apparent that although it accurately anticipated the intensity of long wavelength emissions, it projected limitless total energy when the intensity diverged to infinity for short wavelengths. The event was dubbed the "ultraviolet disaster."

Max Planck proposed in 1900 that the frequency of light produced by a black body was determined by the frequency of the oscillator that emitted it and that the energy of these oscillators grew linearly as frequency rose (according to E = hf where h is Planck's constant and f is the frequency).

When examining five simple harmonic oscillators of equal amplitude but different frequencies, the oscillator with the highest frequency has the greatest energy (albeit this connection is not linear like Planck's).

Planck avoided a catastrophe by requiring that great-frequency light be produced by an oscillator of equal frequency & that the oscillator occupy greater energy than one of a lower frequency.

Giving an equal partition to high-frequency oscillators resulted in fewer oscillators and less emitted light. The less-frequency, low-energy oscillators were repressed, as they were in the Maxwell–Boltzmann distribution, by the assault of thermal jiggling from higher energy oscillators, which had to raise their energy and frequency.

Planck's description of the black body is innovative in that it is based on an integer number of oscillators in thermal equilibrium with the electromagnetic field. As frequently as they are stimulated by the electromagnetic field, these oscillators donate their full energy to the electromagnetic field, producing a quantum of light, absorbing a quantum of light, and starting to oscillate at the appropriate frequency.

Planck had developed an atomic theory of the black body on purpose but had inadvertently produced an atomic theory of light, in which the black body never produces quanta of light with an energy less than hf at any given

frequency. When he realized he had quantized the electromagnetic field, however, he condemned light particles as a restriction of his approximation rather than a feature of reality.

Photoelectric Effect

While Planck used atoms and a quantized electromagnetic field to solve the ultraviolet disaster, most modern physicists concluded that Planck's "light quanta" were really defects in his model.

A more thorough derivation of black-body radiation would result in an electromagnetic field that is completely continuous and "wave-like" with no quantization.

However, in 1905, Albert Einstein used Planck's black body model to solve another pressing issue of the time: the photoelectric effect, in which atoms release electrons when they absorb energy from light. Since their existence was postulated eight years ago, phenomena have been investigated in physics labs all around the globe using the electron model.

Philipp Lenard found in 1902 that the energy of these expelled electrons was determined by the frequency of the incoming light rather than its intensity. When a metal is illuminated with low-frequency light, a few low-energy electrons are expelled.

When a highly strong beam of low-frequency light is now shone onto the same metal, a spate of electrons is expelled; their energy is the same, but there are just more of them. More electrons are expelled when there is lighter.

In order to get high-energy electrons, the metal must be illuminated with high-frequency light. This, like black-body radiation, was at odds with a theory that suggested continual energy transfer between radiation and matter. However, as long as the matter is quantum mechanical in nature, it may still be described using a completely classical explanation of light.

The photoelectric effect could be described relatively easily if one utilized Planck's energy quanta and required that electromagnetic radiation at a particular frequency could only transfer energy to matter in integer multiples of an energy quantum hf.

Because each electron is energized by the absorption of a single photon, less-

frequency light just ejects less-energy electrons. It is because the energy of each photon stays low, increasing the intensity of low-frequency light (raising the number of photons) simply increases the number of excited electrons, not their energy. Higher-energy electrons can only be ejected by raising the frequency of light, and therefore the energy of the photons.

Using Planck's constant h to calculate photon energy based on frequency, the energy of ejected electrons should similarly rise linearly with frequency, with Planck's constant as the gradient of the line. These findings weren't verified until 1915 when Robert Andrews Millikan obtained experimental data that matched Einstein's predictions perfectly.

The existence of photons was not clearly proved until the discovery of the photon antibunching effect, even though the energy of ejected electrons mirrored Planck's constant. It refers to the fact that once a single emitter (atom, solid-state emitter, molecule, etc.) emits a visible light signal, it cannot produce a second signal unless the emitter is re-excited.

As the observation period approaches the excited-state lifespan of the emitter, this results in a statistically measurable temporal delay between light emissions, making detection of numerous signals more improbable.

The impact may be shown in a lab setting for undergraduates.

Photons were the sole explanation for this occurrence. Even though Einstein's "light quanta" were not named photons until 1925, they were the archetypal illustration of wave-particle duality in 1905. Magnetic radiation follows linear wave equations but can only be emitted or absorbed as discrete components, functioning as both a wave and a particle at the same time.

De Broglie's hypothesis

Louis-Victor de Broglie proposed the de Broglie hypothesis in 1924, stating that all matter has a wave-like character. He linked wavelength and momentum as follows:

The equation above is a generalization of Einstein's equation.

De Broglie's formula for electrons was verified three years later when electron diffraction was seen in two separate tests. George Paget Thomson noticed the anticipated interference patterns after passing a beam of electrons

through a thin metal sheet at the University of Aberdeen.

Lester Germer and Clinton Davisson of Bell Labs conducted the Davisson–Germer experiment, which directed an electron beam across a crystalline grid.

In 1929, De Broglie received the Physics Nobel Prize intended for his theory. For their experimental work, Thomson and Davisson received the Physics Nobel Prize in 1937.

Importance

Quantum mechanics is built on the foundations of wave-particle duality. All of a particle's information is stored in its wave function, a complex-valued function approximately similar to the amplitude of a wave at each point in space, according to the theory's formalism. Schrödinger's equation governs the evolution of this function.

This equation contains solutions that take the form of the wave equation for particles with mass. Interference and diffraction are wave-like phenomena that occur when such waves propagate. Schrödinger equation has no solutions for particles with no mass, such as photons. A photon wave function may be built using Einstein kinematics to localize energy in spatial coordinates rather than particle wave’s function, which localizes masses in space.

The particle-like behavior is most obvious owing to quantum mechanics phenomena linked with measurement. The uncertainty principle dictates that when a particle's position is measured, the particle is pushed into a more localized state.

The measurement of the wave function, when seen via this formalism, will result in the wave function collapsing to a highly peaked function at some point. The probability of detecting a particle with mass at any given place is equal to the squared amplitude of the wave function there. Heisenberg's uncertainty principle applies to the measurement, which will yield a well-defined location.

The uncertainty vanished with the discovery of quantum field theory. The wave functions are solutions that obey the wave equation and are allowed in the field. The word particle refers to the Lorentz group's irreducible

representations that are allowed by the field.

The outward legs are recognized to be simplifications of the propagation, while the interior lines are for some order in an extension of the field interaction in a Feynman diagram, which is regarded as a convenient calculational approximation. The occurrences that were previously believed to be paradoxes are explained since the field is non-local and quantized. Quantum field theory produces the same findings within the limitations of wave-particle duality.

Visualization

The standard model and the de Broglie–Bohr theory are two methods to depict the wave-particle behavior.

In terms of the position and momentum space wave functions for one spinless particle with mass in one dimension, here's an example of wave-particle duality as it pertains to de Broglie's hypothesis and Heisenberg's Uncertainty principle. The Fourier transforms of these wave functions are the same.

The more localized the position-space wavefunction, the more probable the particle will be discovered with position coordinates in that area, and the momentum-space wavefunction, conversely, is less localized, resulting in a wider range of potential momentum components for the particle.

Conversely, the more concentrated the momentum-space wavefunction, the more probable the particle will be located in that area with those values of momentum components, and the less localized the position-space wavefunction, the more widespread the position coordinates the particle may occupy.

MORE ABOUT ATOMS AND PARTICLES

Modern particle physics originated as a study of the structure of the atom in the early twentieth century. The gold foil experiments of Geiger, Marsden, and Rutherford, which discovered the atomic nucleus, laid the groundwork for the field. In 1919 (the proton) and 1932 (the nucleus), the components of the nucleus were found (the neutron).

Quantum physics was established in the 1920s to explain the structure of the atom. The binding of the nucleus was beyond the comprehension of the physical rules in use at the time. On the basis of magnetism alone, the protons should repel each other. Yukawa postulated a new force to keep the nucleus together in the mid-1930s, later known as the strong nuclear force. He theorized that a new particle known as a meson was responsible for this force.

In the 1930s, Fermi offered an effective theory of the weak force and suggested the neutrino as the justification for the observed energy spectrum of decay. Anderson discovered the positron and the muon separately. In 1947, Yukawa's meson was found in the form of a pion. The field's emphasis evolved from knowing the nucleus to understanding more basic particles and their interactions through time, and particle physics separated from nuclear physics. During the 1950s and 1960s, scattering investigations revealed a wide range of new particles. The "particle zoo" was the name given to this situation.

Are protons and neutrons foundational? To get out of the "Particle Zoo," the next obvious step was to see whether the patterns might be explained by the hypothesis that all mesons and baryons are made up of other particles. Quarks were given to these particles. Quarks, as far as we understand, are similar to points in geometry. They don't include any other materials. Scientists now believe quarks and electrons are fundamental after rigorous testing. An elementary particle, also known as a basic particle, is a particle that is not

recognized to have a substructure or be made up of many smaller particles. If a subatomic particle has no substructure, it is one of the universe's fundamental particles, from which all bigger particles are formed.

An elementary particle is something that can be broken down further into its constituent parts. To further comprehend the particle, we'll use an example that everyone can understand: a home. We'll proceed to zoom in on this home. When you look at a home from a distance, all you see is a house. As you get closer to the home, though, the building bricks, roof panels, windows, and entrance become more obvious. In essence, the home is made up of many parts. The construction bricks are made out of tiny stones and cement, as you can see if you look closely. When you look at the door, you can see many components such as glass, paint, wood, latch, hinges, and so on. We may zoom in even further, for instance, on the pebbles in the cement. We may attempt to zoom in even further. Still, we will eventually hit the limit of our eyes' visual capabilities, rendering us unable to see molecules that make up the little stones any further. Atoms make up molecules. However, these atoms may be broken down into protons and electrons. The latter two building components are known as “elementary particles” by physicists. According to scientists, these particles could be further divided into smaller ones. Physicists have summarized all the elementary particles in the Standard Model. As a result, a subatomic particle is microscopic. “The shortest length we've defined is 1036 meters, which corresponds to a particle's dimension. Suppose what would happen if we took a particle approximately 0.1 mm in size, which generally represents the small cell that can still be seen with the human eye, and extended it to the magnitude of our universe. The smallest dimension in this new world would be 0.1 mm. You may probably guess that you wouldn't be able to see this unit of measurement with your naked eye. This would be impossible even with a microscope since it only magnifies to about 1010 m, the size of one atom. As a result, one crucial challenge is how to assess something you can't see. This is where CERN's particle accelerator comes into play.

Types of Particles

Particle type		Strong interaction	Weak interaction	Electromagnetic interaction	Spin
Leptons		No	Yes	Some	1/2
Hadrons	Mesons	Yes	Yes	Yes	integer
	Baryons	Yes	Yes	Yes	half-integer

Interaction carriers

Interaction	Gauge-boson
strong	gluon
weak	$W^{\mp}, Z$
electromagnetic	photon (γ)

Leptons

Leptons include the electron and neutrino. They are involved in weak interactions, while the electron, an electrically charged particle, is also involved in electromagnetic interactions. They don't have a lot of interaction and aren't located within the nucleus.

This implies how they pair with W± and Z bosons and how the electron links to the photon in gauge boson coupling. Between leptons and gluons, there is no connection.

Each "family" or "generation" of particles is duplicated three times in nature. As a result, two particles with characteristics comparable to the electron (electric charge -e, spin-1/2, weakly but not strongly interacting) exist. These are known as the muon (μ) and tau (τ). They each have their own neutrino, νμ and ντ respectively.

Thus, the six leptons are

Leptons			Electric Charge
ν_e	ν_μ	ν_τ	0
e	μ	τ	-1

The electron mass is 0.511 Mev/c2, the muon is 106 Mev/c2, and the tau is 1.8 GeV/c2. The higher charged leptons may decay into an electron, a neutrino, and an anti-neutrino through weak interactions. A W- is emitted by the charged lepton, which then changes into its own neutrino. The W- then transforms into an electron-type anti-neutrino, similar to how a neutron decays into an electron and an electron-type anti-neutrino.

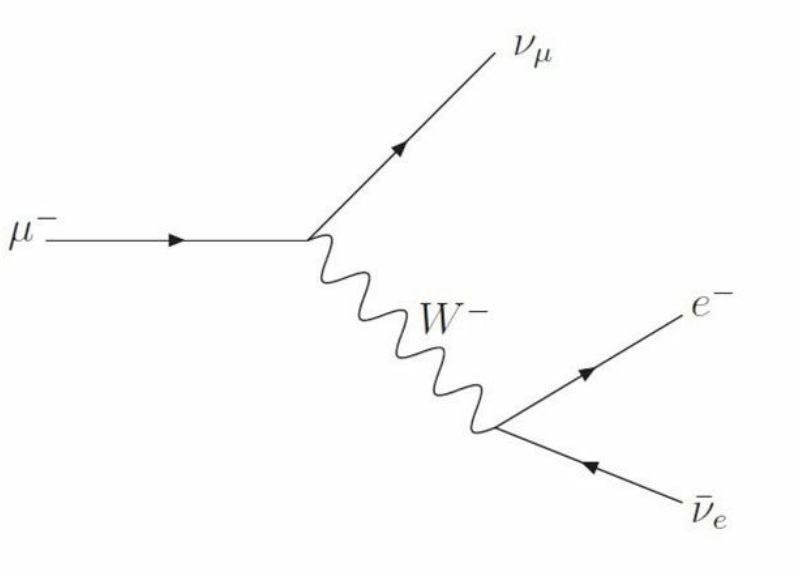


Figure 9: Leptons

The muon does have a half-life of around 2 x 10-6 s. At the same time, the tau has a half-life of about 3 x 10-11 s.

In the same way that the electron has an antiparticle (positron) with a positive electric charge and the same mass and spin, the μ -, and ¿ - also have antiparticles, μ+, and ¿+, respectively. Likewise, νμ and ντ have antiparticles ν-μ and ν-τ, respectively.

Hadrons

These particles are involved in strong interactions. "Mesons" refer to hadrons with integer spins (bosons), whereas "baryons" refer to hadrons with half (odd) integer spins (fermions).

So far, well over a hundred of each variety have been discovered. As a result, hadrons are no longer regarded as elementary particles (although leptons are likely to be) but rather are made up of elementary spin-particles known as "quarks."

Mesons may have integer spin since they are the bound states of a quark and an anti-quark. Baryons are three-quark bound states that may have either spin- or spin+.

The proton is the only hadron that is completely stable (it has a lifespan of more than 1032 years!). Protons, leptons, and photons are the end products of all other hadrons.

Hadrons engage in all interactions because of the quarks that make them.

In every encounter, there are three generations of quarks, just as there are three generations of leptons.

Quarks			Electric Charge
u	*c*	*t*	+2/3
d	*s*	*b*	-1/2

Some hadrons can only decay weakly because they can't decay through strong interactions (the neutron is such an example). This is due to the fact that quarks exist in a variety of flavors, which are preserved by strong interactions. The meson K-, for example, is the bound state of an s-quark and ū anti-quark. The s-quark has a flavor termed "strangeness" (the s-quark has strangeness -1, and its antiparticle has strangeness +1 due to sad historical circumstances). Because the K- is the lightest meson with an s-quark, it cannot decay through strong interactions.

Because the weak interactions do not always preserve flavor, the s-quark may decay into a u-quark, producing a W-, which decays into an anti-neutrino and an electron. The last state meson is the bound state of a u-quark and its anti-quark that may combine to generate a neutral pion, π0. As a result, the decay

K- → π0 + e- + ν-e

Can go on with the weak interactions. The K- has a lifespan of 1.2108 seconds (another long-lived particle).

On the other hand, a meson K*- is a bound state of an s-quark and ū anti-quark, but in an excited state with a mass larger than that of a K- and a π0.

The decay

$K^{*-} \rightarrow K^- + \pi^0$,

Since the flavor is maintained, it may continue through strong interactions (note that an antiquark has always had the opposing flavor of the corresponding quark, implying that a π^0 is flavor neutral). The lifetimes of particles that may decay due to strong interactions are typically 10-23 seconds.

Atoms in Motion

What expression would contain the greatest knowledge in the fewest words if all scientific understanding was lost in a disaster and only one phrase was handed on to future generations of creatures? All things are comprised of atoms, according to the atomic hypothesis. Atoms are little particles that move continuously, attracting one another when separated by a small distance but repelling when pushed together. If you apply a little creativity and thought to just one line, you will discover a great quantity of knowledge about the world.

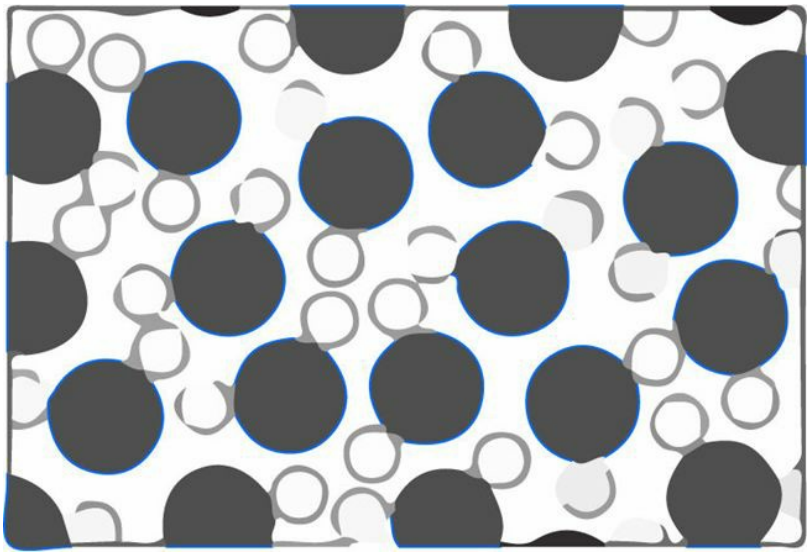


Figure 10: Water magnified a billion times

Consider a single drop of a quarter of an inch on each side to demonstrate the strength of the atomic concept. We can see nothing except water if we look carefully enough—smooth, uninterrupted water. Even if we magnify it two thousand times with the finest optical microscope available, the water drop

will be about forty feet across, about the size of a large room, and if we looked very closely, we would see fairly smooth water—but in between small football-shaped items swimming back and forth. It's quite intriguing. These are parasitic fungi known as paramecia. You may stop here and be so fascinated by the paramecia's writhing, twisting bodies and cilia that you don't want to go any farther, except perhaps to enlarge the paramecia even more and see inside. Of course, this is a biology topic, but for the time being, we'll focus on the water substance itself, amplifying it two thousand times. Now a drop of water is approximately fifteen miles wide, and if we look carefully at it, we can see a type of swarming, something that is no longer smooth—it resembles a gathering at a football game as viewed from a great distance. We'll enlarge it another 250 times and see what this swarming is about, and we'll see anything similar to what's seen in Figure 10. This is a billion-fold enlarged image of water that has been idealized in numerous ways. First and foremost, the particles are formed crudely with sharp corners, which is wrong. Second, they are almost schematically depicted in a two-dimensional layout for simplicity, although they move about three dimensions. It's worth noting that the atoms of hydrogen (white) and oxygen (black) are represented by two types of "blobs," or circles, and each oxygen molecule contains two hydrogens attached to it. (A molecule is defined as a small group of oxygen-containing two hydrogens.)

The image is further enhanced by the fact that genuine particles in the environment are constantly jiggling, bouncing, rotating, and twisting towards one another. You'll have to think of this as a moving image instead of a static one. Another feature that cannot be shown in a painting is the reality that particles are "stuck together"—that they are attracted to one another, with one pulling on the other, and so on. The whole group is, in a sense, "glued together." The particles, on the other hand, do not push through each other. If you attempt to press two of them together too tightly, they will resist each other.

The atoms have a radius of 1 or 2 108 cm. We claim they are one or two angstroms in radius since 108 cm is termed an angstrom (by another name). Another approach to recalling their size is to imagine an apple multiplied by the size of the world, with the atoms inside the apple being about the same size as the original apple.

Imagine a large bit of water with these jiggling particles hooked together and tagging along. Because of the magnetism of the atoms towards each other, the water maintains its volume and does not disintegrate. The water will flow if the drop is on a slope where it may travel from one location to another, but it will not disappear—things do not fly apart—due to molecular attraction. Now, the wobbling motion is just what we refer to as heat: as the temperature rises, so makes the motion. If we heat water, the jiggling rises, and the space between the molecules increases, and if we keep heating, the pull between both the molecules will eventually be insufficient to keep them together, and they will fly apart by becoming separated. In fact, that's how we get steam from water: we raise the temperature, which causes the particles to fly away due to the greater velocity.

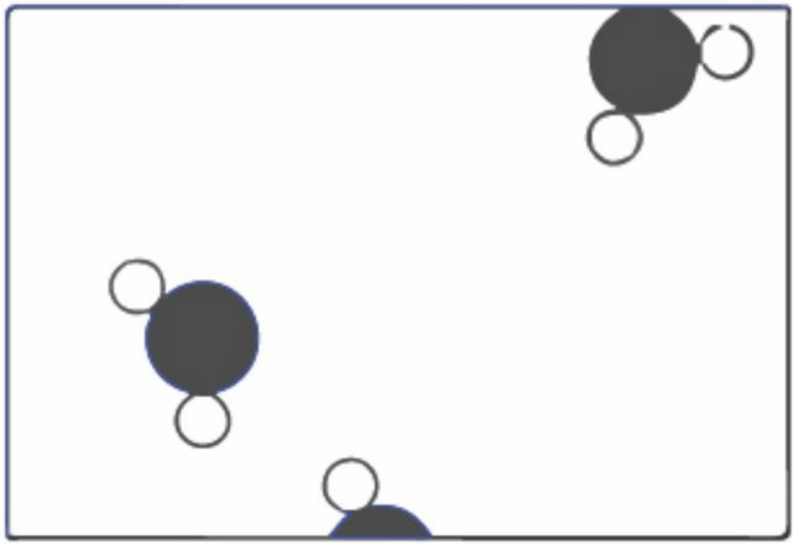


Figure 11: Steam

At normal air pressure, this figure would not contain more than three water molecules. Most squares of this size would have none, but we have two or a half or three. We can now see the distinctive molecules of steam more clearly than we do in the water. The molecules are depicted with the hydrogen atoms at a 120-degree angle for simplicity. We know this molecule extremely well since the angle is 1053, and the length between the center of the hydrogen and the center of oxygen is 0.957.

Let's take a look at some of the characteristics of steam vapor or any other gas. Because the molecules are isolated from one another, they will bounce

off the walls. Imagine a room filled with a hundred or more tennis balls that are constantly bouncing about. When they blast the wall, it moves away from them. (Of course, we'd have to reposition the wall). This implies that the air exerts a restless force that our crude senses (which aren't multiplied a billion times) perceive as just a little push. Pressure must be applied to contain gas.

Let’s see Figure 12, a conventional vessel for retaining gases, a cylinder with such a piston. For now, the form of water molecules doesn't matter, so we'll represent them as ping pong balls or small dots, for simplicity's sake. These objects are constantly moving in every direction. Because so many of them are constantly striking the top piston, we'll have to hold it down with a specific force that we call the pressure to protect it from being slowly pushed out of the container by this constant pounding. Clearly, a force is equal to the area since if the area is increased while the molecules per cubic centimeter remain constant, the frequency of crashes with the piston will grow in the same ratio.

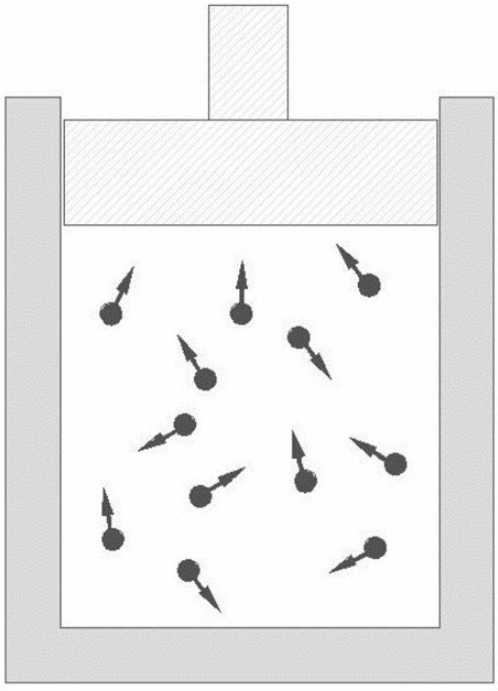


Figure 12: Standard vessel for holding gases

Now, increase the number of particles in this tank to double the density and keep them moving at the same rate, i.e., at the same temperature. As a result, the frequency of crashes will roughly double, and because each will be

equally "energetic," the pressure will be proportional to the density. If the fundamental nature of the interactions between the atoms were considered, we would anticipate a tiny drop in pressure due to atom attraction and a slight rise due to the limited volume they occupy. Nonetheless, if the volume is high enough that there aren't many atoms, the force is dependent on the density to a good approximation.

Another item to consider is what would happen to the pressure if we raised the temperature without increasing the strength of the gas, i.e., if we increased the speed of the atoms. The atoms strike harder as they travel quicker, and they also hit more often, increasing the pressure. You can see how straightforward the concepts of the quantum model are.

Consider a different scenario. Assume that the piston advances inward, gradually compressing the atoms into a smaller region. What happens when an atom collides with a moving piston? It seems to gain speed as a result of the impact. You may test it by deflecting a ponging ball off the forward paddle, for instance, and you'll see that it bounces off faster than it went in (for instance, if a piston strikes an atom that is standing stationary, it will undoubtedly move.) As a result, as the atoms leave the piston, they are "hotter" than they first hit it. As a result, all of the atoms in a vessel will still have increased their speed. This indicates that as we gently compress a gas, the gas's temperature rises. As a result, the temperature of a gas will increase under slow compression and drop in temperature with slow expansion.

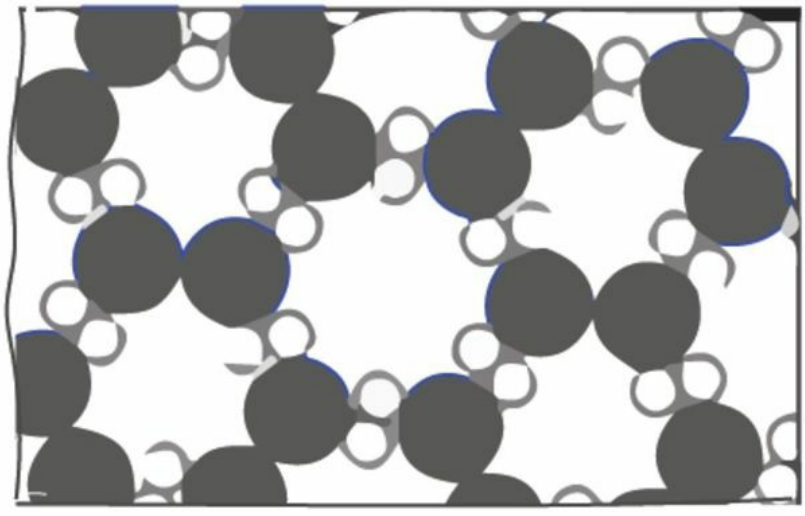


Figure 13: Ice

Returning to the drop of water, we now move our gaze in a different direction. Let's say we reduce the temperature of our water droplets. Assume that the wobbling of the atoms' molecules in water is continuously diminishing. We know that there are attractive forces between atoms. Therefore, they won't be able to jiggle as well after some time. At very low temperatures, the molecules bind into a new pattern, which is ice. Because it's in 2 dimensions, this schematic representation of ice is incorrect, but it is qualitatively correct.

The interesting observation is that every atom has a definite location in the material, and you can conveniently appreciate that if you were to grab all the atoms placed at a single end of the drop in a specific arrangement, each atom in a specific location, then the other end, miles away, will have a definite location because of the rigid structure of interconnections. In contrast to water, where the framework is broken down due to increasing jiggling, and the atoms constantly move about in various ways, if we grasp an ice needle at one end, the other end resists us pulling it away. The difference between liquids and solids is that in a solid, atoms are set up in a crystalline array and do not have an arbitrary position over long distances; the position of atoms on one side of a crystal is defined as the position of billions of atoms right on the other part of the crystal. Although including many of the proper characteristics of ice, it is a made-up ice arrangement that is not the real thing.

One of the proper aspects is that there is a hexagonal section in the symmetry. You can see it if we rotate the image by 60 degrees. It returns to its original position. As a result, the six-sided structure of snowflakes is due to symmetry in the ice. Another reason that it demonstrates is really why ice shrinks whenever it melts. The actual ice structure, like the crystal structure of ice illustrated below, has numerous “holes” in it. Molecules may fill these voids when the structure breaks down. Apart from water or certain types of metal, most simple substances expand when melted because atoms are tightly packed inside the solid crystal and require more area to wiggle about when melted, whereas an approach when working collapses, like water.

Despite the fact that ice has a "rigid" crystalline shape, its temperature may alter since it contains heat. We can modify the quantity of heat if we want to.

What is the temperature of ice? The atoms do not remain still. They're shaking and jiggling. So, despite the fact that the crystal has a specific order —a precise framework of the atoms vibrate “in place.” They vibrate with increasing amplitude as the temperature rises until they are shaken out of position. This is referred to as melting. The vibration of the atoms reduces with decreasing temperature until, at zero, there is indeed a minimal amount of vibration that the atoms may have, but it is not zero. With the exception of helium, this minimal quantity of atom motion is insufficient to melt a material. Helium just reduces the atomic movements as far as possible, but there is still sufficient motion to prevent it from freezing at absolute zero. Helium does not freeze at absolute zero unless the temperature is high enough to cause the atoms to smash together. We can cement it by increasing the pressure.

Atomic Processes

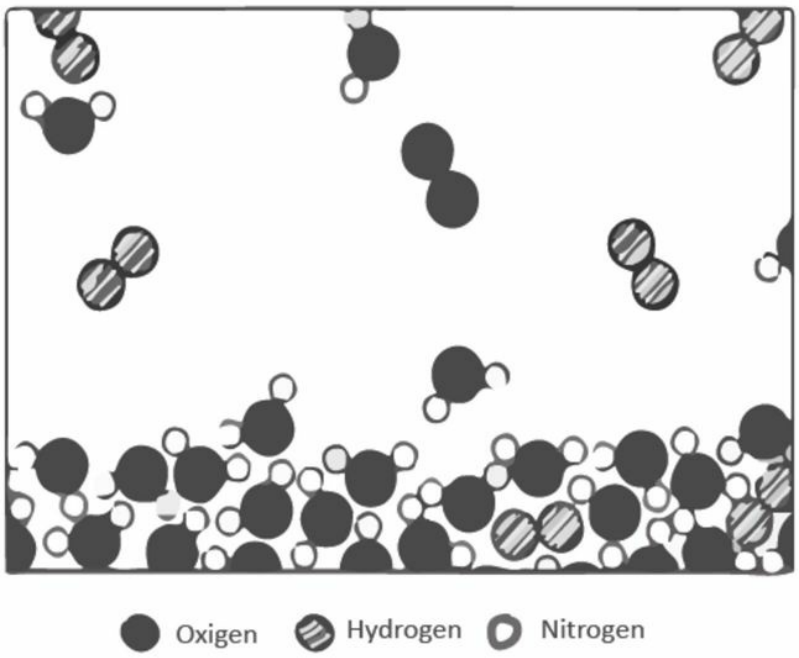


Figure 14: Water evaporating in the air

That's all there is to the atomic explanation of liquids, solids, and gases. However, the atomic theory also defines processes, so we'll look at a few of them from that perspective. The first process we'll look at involves the water's surface. What occurs at the water's surface? By believing that a surface is suspended in air, we may make the image more complicated and lifelike.

Figure 14 shows the surface of the water in the air. We could still see the water particles creating a body of water vapor, but now we can also see the water's surface.

A variety of objects may be found above the surface: First and foremost, there are H2O molecules, which are present in steam. This is water vapor, which exists above liquid water at all times. (An equilibrium exists between steam vapor and water, which will be discussed later.) There are also some other molecules—here, two oxygen atoms are bonded together to create an oxygen molecule, and two nitrogen atoms are also bound together to form a nitrogen molecule. Air is nearly completely made up of nitrogen, oxygen, and a small quantity of water vapor, with minor quantities of argon, carbon dioxide, and other gases. So, above the water's surface, there is air, a gas containing some water vapor. So, what's going on with this image? The molecules of water are constantly jiggling. Sometimes, someone on the surface is struck a bit harder than normal and is knocked away. Because the image is stationary, it is difficult to see what is going on. However, we may assume that one molecule at the surface has been struck and is flying away or that another has been struck and is flying away.

As a result, the water evaporates molecule by molecule. However, if we sealed the vessel above, we would discover a huge number of water molecules among the air molecules after some time. Every now and then, one of these vapor molecules flies down to the water and becomes lodged. As a result, we can observe that what seems to be a lifeless, boring object—a glass of water with a cover lying there for possibly twenty years—contains a dynamic and fascinating event that occurs all the time. Nothing seems to be changing to our naked eyes, but if we could magnify it a billion times, we would realize that it is constantly changing itself from the point of view: molecules leave the surface and return.

Why aren't we seeing any progress? Because there are just as many molecules going as there are returning! “Nothing happens” in the long term. When we remove the top of a vessel and blow away the moisture in the air, replacing it with low humidity, the number of water molecules that leave is the same as before because it is dependent on the wobbling of water, but the number of molecules that return is greatly reduced because there are so few

water molecules well above water. As a result, more people are leaving than entering, and the liquid evaporates. As a result, switch on the fan if you want to evaporate water!

Here's another example: Which molecules are the ones that leave? When a molecule departs, it is owing to an unintentional, additional buildup of energy, which it requires to break free from the enticements of its surroundings. As a result of individuals who depart having more power than the average, those who remain have less ordinary motion than before. As a result, the liquid progressively thickens.

As a result, when a liquid evaporates, it usually cools. Whenever a molecule of vapor travels from the air to the water below, it encounters a strong attraction as it reaches the surface. This causes the approaching molecule to accelerate, resulting in the creation of heat. As a result, they take the heat with them; when they return, they produce heat. Of course, if there is no overall evaporation, the outcome is that the water temperature does not change. The cooling of water is done by blowing on it to maintain a constant majority in the number of molecules evaporating. As a result, blow on the soup to chill it down!

Of course, you should be aware that the processes we've just detailed are much more intricate than we've explained. The water not only evaporates into the air, but one of the nitrogen or oxygen molecules may sometimes enter and "get lost" in the bulk of water molecules, eventually making its presence in the water. As a result, the air dissolves easily in water, oxygen or nitrogen molecules diffuse into the water, and the water becomes air-filled. If we immediately remove the air from a vessel, the air molecules will leave the vessel faster than they enter, causing bubbles to form. As you may know, this is quite dangerous for divers.

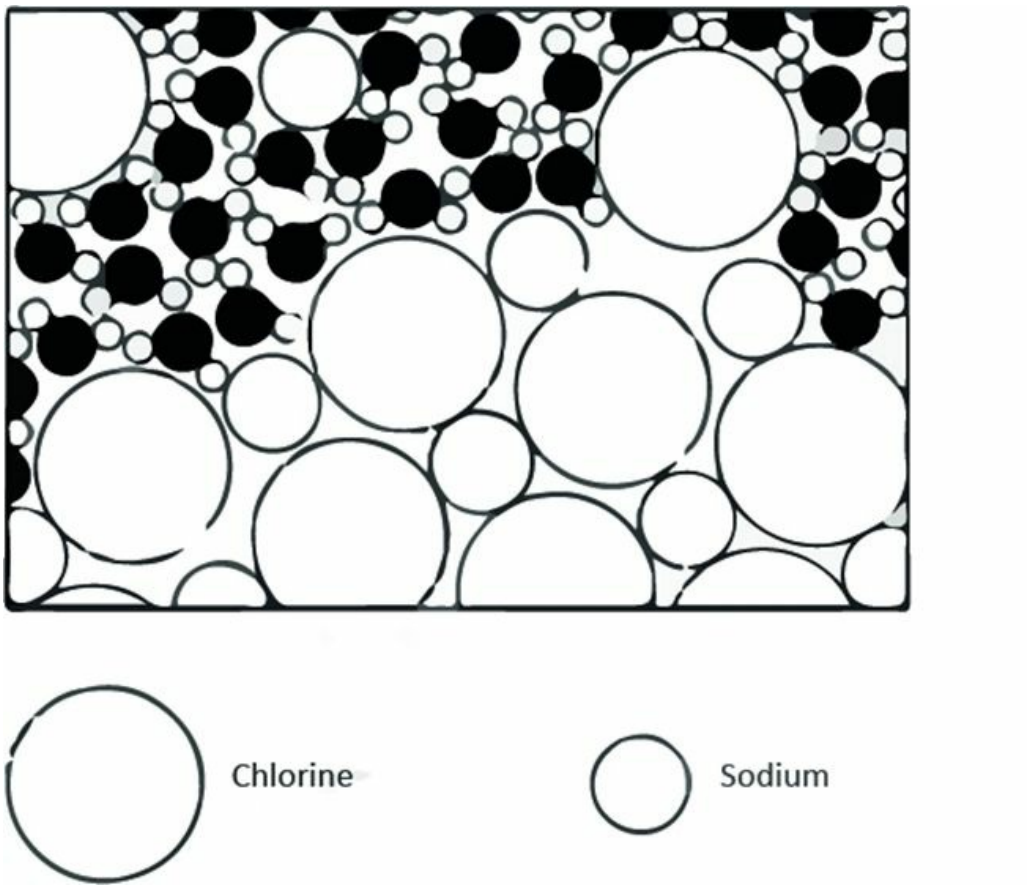
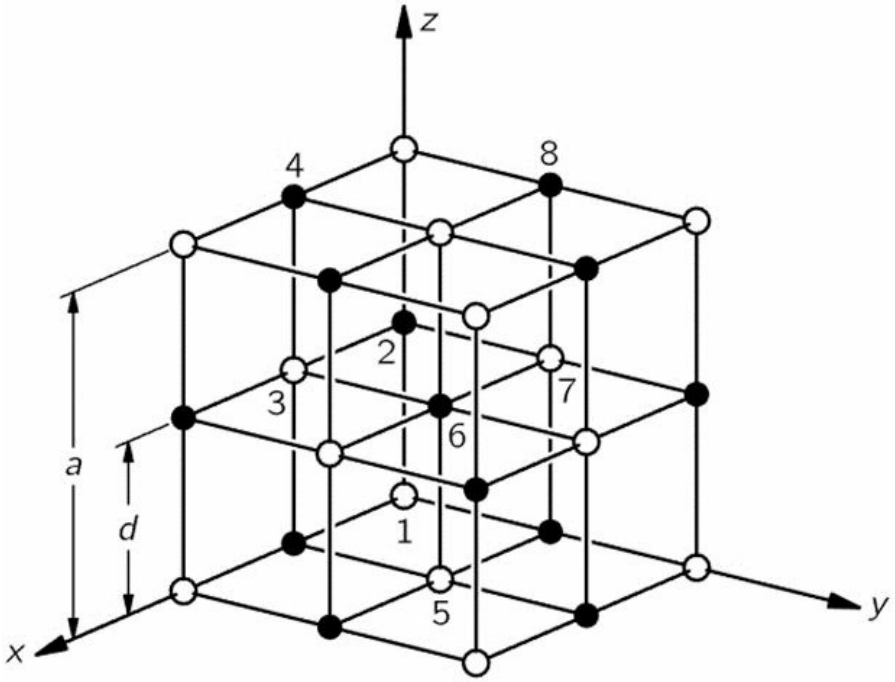


Figure 15: Salt dissolving in water

Now we'll go on to the next step. In Figure 15, from an atomic standpoint, we can observe a solid material dissolving in water. What happens if we put a salt crystal in the water? Salt is indeed a solid, a crystal, and a well-ordered collection of "salt atoms."

Figure 16 is an illustration of the trio composition of salt, sodium chloride. The crystal, strictly speaking, is made up of ions rather than atoms. A group of atoms or a single atom with a few additional electrons or a few electrons that have been lost. Chlorine ions and sodium ions are found in salt crystals. When we put the ions in solid salt, they all cling together by electrical attraction, but when we put them in water, we notice that some of the ions jiggle free due to the ions' attraction to negative oxygen and positive hydrogen.

Crystal	●	○	a (Å)
Rocksalt	Na	CI	5.64
Sylvine	K	CI	6.28
	Ag	CI	5.54
	Mg	0	4,2
Galena	Ph	1s	5.97
	Pb	Se	6.14
	Pb	Te	6,34



Nearest neighbor
distance $d = a/2$

Figure 16: The three-dimensional structure of common salt, sodium chloride

In Figure 15, we can observe a chlorine ion loosening and some other elements floating in the water in the form of ions. This image was created with care. Because sodium is positive as well as the oxygen end of the water is negative, they attract electrically; the hydrogen endpoints of the molecules of water are more likely to be close to the chlorine ion, while the oxygen end

is more likely to be close to the sodium ion. Is it possible to distinguish whether the salt decomposes in water or crystallizes out of water based on this image? Of course, we can't know since some atoms are exiting the crystal while others are returning. The process is dynamic, similar to evaporation, and it is dependent on whether there is almost as much salt inside the water as is required for equilibrium. When we talk about equilibrium, we're talking about a scenario where the rate at which atoms leave and return is exactly the same. When the water has nearly no salt, more atoms escape than return, causing the salt to dissolve. However, if there are far too many "salt atoms," more remain than leave, and the salt crystallizes.

In passing, we should point out that the idea of a substance molecule is simply a rough approximation and only applies to a limited set of substances. In the water, it is obvious that the three atoms are bonded together. In the case of NaCl in solid form, the situation is less apparent. Only the sodium and chloride ions are arranged in a cubic configuration. There really is no logical way to classify them as "salt molecules."

Returning to our previous explanation of solution and deposition, raising the temperature of a salt solution increases the pace at which atoms are carried away, as well as the rate at which atoms are returned. It turns out that predicting which way things will go, whether anything or less of the solid will melt, is quite difficult in general. As the temperature rises, most compounds dissolve more readily, while others dissolve less freely.

Higgs Field and Boson Explication

The Higgs field is just a field of force that spreads across the cosmos like molasses in a large vat. The majority of particles that pass through it adhere to the molasses, slowing them down and making them heavier. The Higgs boson is the particle that aids in the transmission of a mass-giving Higgs field, analogous to how a photon communicates with the electromagnetic field.

What is the Higgs boson?

A Higgs boson is a subatomic particle, meaning it can't be broken down anymore into tiny particles and can't be observed with the human eye or under a microscope. Yet, some fifty years ago, scientists were almost positive

of its existence. This occurred because Mr. Higgs and a few other scientists had mathematically proven that the principles of physics were only true if the Higgs field existed. We still understand a lot about how the world is put together without the Higgs field: it's made up of very small particles. But we couldn't figure out why things were so heavy or how they had any weight at all. They were certain that a Higgs field existed since there would have to be an explanation for objects' having weight. A field, on the other hand, is even harder to detect than just a particle, but since a field has always been associated with a particle, scientists knew exactly what they were looking for: a Higgs boson.

How was the Higgs boson detected?

Experts at CERN and scientists from other colleges and institutes have been working for years to prove the presence of a Higgs boson. Protons collided at CERN at very high speeds, causing them to disintegrate into smaller particles. Consider slamming a pane of glass against a wall: the more force used, the more shards are generated, and the farther these shards go. However, you have no control over how these pieces are created. You can't make the glass break into 1 x 1 cm fragments by telling it to. Discovering a shard that fits the dimensions is merely a remote possibility. You can't tell two protons to split into Higgs bosons if you follow this reasoning. There's a slim chance that a Higgs boson will appear. Then there's the problem that the detector can't directly 'see' the Higgs boson since its lifetime is so short before it decays into various particles. These particles eventually wind up inside the detectors that are erected all around the tunnel. We may occasionally tell whether particles came from the Higgs boson based on the mix of particles. The chances of a Higgs boson arising from a collision are slim, let alone establishing whether or not it is a Higgs boson. You can only imagine the massive number of accidents required, each of which had to be meticulously examined, which is why it took ages for physicists to be certain that they had discovered the Higgs boson.

How does the Higgs field function?

Particles, and consequently everything everywhere, have weight because of the Higgs field. The particle that passes through the Higgs field determines whether or not it is given weight by the Higgs field. This field affects every

particle, but different particles are impacted to varying degrees. Some particles (heavy particles) are slowed by the field, while others fly straight through it, hardly affecting them. As a result, a Higgs field is essential for conferring weight on a particle. Consider the Higgs field being represented by a large number of individuals in a room to bring this into perspective (see illustration). The people in a room are also there to socialize. Therefore, they are unlikely to leave. A door at one end of the room allows fresh individuals (particles) to enter. The individuals in the room ('the Higgs field') do not recognize the new individual and are undisturbed by their presence whenever a person of low status arrives. Consequently, the individuals in the space will continue to socialize, but the newcomer will be able to roam about freely (the 'weightless particle'). When a celebrity walks into a room, all eyes are on him or her, and people rush to encircle him or her. It becomes much more difficult to move about the room after that. The celebrity's property (famous or not) assures that the people around him or her act in a specific manner, slowing down the star. This is similar to how the Higgs field works: a particle's attributes trigger a response from the Higgs field, which may cause the particle to become heavy. The Higgs field's beauty is that it is ubiquitous, which means that all particles having mass would have the same mass anywhere and at all times.

A Higgs boson is just so minuscule that it can't be seen with a microscope. As a consequence, the particle can't be directly investigated. So, how does science know this particle's existence and what its characteristics are? The Hadron Collider in Geneva, as previously established, accelerates and collides hydrogen atoms. This is done at very high speeds, allowing the particles to disintegrate when they collide. The hitting protons carry a significant amount of energy as a consequence of the acceleration, and they divide into numerous new particles as a result. The particles produced by this collision might contain Higgs bosons and other basic particles. The detectors surrounding the collision location may be used to measure the qualities of the nanoparticles that result from the impact. There are two types of scientists working on the Higgs boson: those who are more interested in practical research and those who are more interested in the theoretical study. The old category includes Radboud Science Award winners Nicolo de Groot and Frank Filthaut. This implies they are more engaged with the particle detection

equipment as well as the software required to assess the detection data. They also strive to comprehend the data's consequences. Good predictions are necessary to appropriately analyze the detection data. These forecasts are made by scientists who are interested in theoretical research. A lot can be determined about the characteristics of the Higgs boson and other basic particles based on the theoretical study.

Researchers may progressively unravel the enigma of how the universe is put together by utilizing particles to verify the predictions of many hypotheses. For research into the Higgs boson, the particle accelerator at Geneva is critical. A large number of scientists from several nations are involved in the study. However, many of these experts, such as Nicolo and Frank, who study at Radboud University in Nijmegen, do their research there. They work on research methods for elementary particles alongside colleagues at the Institute of Practical High Energy Physics. Other theoretical studies on elementary particles are being done by other academics at the same university. You may be asking how they're able to do this when they're not in Geneva. For practical research, experts at universities or researchers based in Geneva maintain frequent communication.

Furthermore, the majority of research, such as data gathering, may be done from anywhere. Researchers who are formulating ideas and forecasts are in the same boat. The winners of the Radboud Sciences Awards, Nicolo de Groot and Frank Filthaut, both helped with the practical investigation of the Higgs boson, notably through the analysis of detection data that allowed for the determination of the particle's characteristics. The Radboud Science Prize winners mostly contributed to solving the first question. However, their study also addressed the second topic, which is concerned with the use of models that anticipate the appearance of new particles.

QUANTUM PHENOMENA

Quantum Entanglement

Quantum Entanglement refers to a physical phenomenon in which two or more particles interact and then become "linked" so that, no matter how far apart they are, an action performed on one particle will affect the state of the other. For example, if you change the polarization of one photon from vertical to horizontal, then the other particle's polarization will automatically be changed from horizontal to vertical. The important word here is "automatically." There's no way this can happen unless they send each other a signal. In this case, it's a change in magnetic field strength along a wire. There is no way for this to happen without one particle having an effect on the other. For example, if you make a measurement of the polarization of one photon and find it to be vertical, there is no way for that information to pass through space and cause the polarization of another photon somewhere else to spontaneously change from horizontal to vertical. Only if the two photons get entangled in some way could this happen. Otherwise, we would just have particles A and B which are both polarized vertically, and particle C which is polarized horizontally.

Quantum Tunneling

Quantum Tunneling is a phenomenon that occurs when electrons and positrons can tunnel through barriers, they would normally not be able to. It is most often observed in the context of particle accelerators and is crucial for understanding how particles behave within certain plasma environments.

The field of physics has many topics that are difficult to understand due to their high degree of technicality and complexity. Unlike other scientific topics, such as the Big Bang Theory or the latest breakthrough in the search for the Higgs Boson, Quantum Tunneling is something that can easily be understood by most people.

Some of you may know, or may not know but just assume to be true, that atoms are made up of negatively charged electrons and positively charged protons. Atoms get their charge from their surroundings which consist of

molecules and other atoms. Atoms, therefore, take on the charge of their surroundings but can also have a neutral charge if there is no net charge in the vicinity.

If an atom had no net charge it would usually be moving around at a constant velocity. However, if there is some type of barrier preventing the particle from reaching its destination, it cannot reach maximum velocity. Before reaching its final destination, the particle will slow down to a certain point where it can reach no further, and then will appear to vanish. Essentially it bounces back on itself because there is some type of force that prevents it from continuing any further. The particle has essentially tunneled through the barrier because it cannot continue at full speed.

Quantum Tunneling is a slow process that occurs in particles traveling through plasma. This happens because there are small amounts of energy (such as X-rays) around which prevent them from reaching their maximum speeds. Quantum Tunneling is crucial for particle accelerators, specifically the Van de Graaff Accelerator. This is because it allows particles to tunnel through plates without resistance, which means that more particles can be accelerated at a time, unlike conventional accelerators which have to stop accelerating for parts of the cycle.

Superconductivity

Superconductivity is a phenomenon that occurs at low temperatures when a material can conduct electricity with zero resistance. It's true that this sounds too good to be true. That being said, even though superconductivities don’t exist in everyday life, the principles behind them do have their applications in everyday life.

In terms of concept and application, superconductivity can be applied to just about anything from electricity to magnetism. In fact, theory predicts that the universe would halt if it were not for superconductivity's existence within certain materials or fields--it creates an energy-carrying medium that allows the universe to function.

The development of superconductivity had an enormous impact on the world, it revolutionized how we view energy and even revolutionized the way society views itself. After the discovery of superconductors, more research

was put into their development to curb any possible issues. Luckily, results only seemed to confirm that there were no problems with this phenomenon.

Today, scientists are working towards making better materials that specialize in this field. They are looking into developing materials that can conduct electricity without resistance at room temperature; this might not apply to everyday life but will be powerful for many fields of science and even more important for society as a whole. A material like this could allow homes to utilize "zero-power electricity.

Superconductors are also used in a wide range of devices, from magnetometers to medical technology. There is still a great deal of room for improvement when it comes to superconductors and the applications for superconductors. In 2013, a team of researchers figured out how to make a "resistance-free power flow" with iron pnictides which led them to use this new knowledge to create a nano-generator that can create electricity from ambient air pressure which is important for certain applications such as wireless sensors and implants.

Superposition

Superposition is a quantum mechanical phenomenon in which an electron placed at two different positions of a magnetic field can be observed to behave like either one of the positions.

This superposition effect is observed when the electron moves through a magnetic field created by another charged particle, such as cosmic rays, and some electrons will survive this move. This phenomenon only occurs in hydrogen and helium atoms where both atomic numbers are equal to 1.

So far, there are two theories about how this works in light atoms with atomic numbers greater than 1, but they don't represent many different conclusions.

When the electron is placed in the magnetic field, it becomes a wave, which means that it can be observed in two different positions at once. When this happens, the electron does not stay at one of the positions but jumps between them. When an electron does that, it becomes a particle again and falls down to one of the positions. Even though this behavior seems like a paradox, superposition is quite real and has great importance in quantum physics.

Superposition can sometimes come out of nowhere because it relies more on probability than actuality. You can't tell which location an electron is in until you observe it; you can only compute probabilities for where it will end up after a certain amount of time has passed. Superposition explains the non-intuitive phenomena in quantum mechanics and can be demonstrated with several experiments.

A classic example of superposition is the double-slit experiment, where a single photon can go through two slits at once instead of one. This phenomenon was demonstrated by Thomas Young in 1801 when he set up a simple experiment to figure out whether light behaved like waves or particles. Young produced two pairs of narrow slits about 30 cm apart, which go through both sets of slits by one light beam source. The light he used was the sunlight that had passed through a colored glass that provided different colors, thus it contained many different wavelengths.

Schrödinger's Cat

You may have heard the story of Schrödinger's cat, but do you really know what it implies?

It was 1920, and Erwin Schrödinger, a German physicist, proposed a thought experiment that seemed to defy logic. He hypothesized that if he put a live cat in a sealed box with an apparatus containing radioactive material inside it. If the radiation released any particles—later named 'cats'—in the subassemblies of the apparatus, they would trigger hammer strikes on an alarm clock set to go off after one hour had passed. The presence of these particles would be detected by the Geiger counter also placed inside this sealed box.

The cat would, in other words, be dead until the alarm went off. The problem was that the radioactive material might decay prematurely, or that some mechanical interference would trigger the hammer even before it was needed. How could Schrödinger know what was going to happen?

He couldn't. He had no idea if his cat would live or die. And he didn't yet know what the consequences of this experiment were… not for him, and not for anyone else either. It is because of this uncertainty that he called his thought experiment 'Schrödinger's cat.

Theoretical physicists have already simulated this thought experiment on a computer and found that it is impossible to predict whether this poor cat will come out of the box alive or dead. Even if you perfectly understand the quantum physics involved, you can't say what will happen. The future of Schrödinger's cat is uncertain; the future of Schrödinger's cat is subjective.

Schrödinger created his thought experiment as a protest against the notion that the collapse of the wave function—the wave function describes quantum particles as waves, and their behavior as probabilities—implies that quantum mechanics describes everything as fundamentally random. Schrödinger himself thought that the world was governed by laws that were more likely to be deterministic than random.

Schrödinger's cat reveals that this view is incorrect. True, you can't predict, at least with certainty, what will happen to the cat in the box. But you don't have to predict its fate—as long as you know there is uncertainty about it.

The theory has not predicted the outcome of Schrödinger's experiment very well so far, except for a few special cases where quantum theory tells us that probabilities are almost certainties. The cat will probably end up either dead or alive. But according to quantum theory, neither outcome is ever certain. The cat could be alive or it could be dead until one of the subassemblies in the box delivers its hammer blow to the clock. And no one can predict what will happen after that.

Quantum Spin

Quantum Spin is a newly discovered and classified type of wave that can change its polarity to become "bottom" or "top." The phenomenon was first reported in 2016 by scientists from the University of California, Santa Barbara. Professor Ilya Blinov has been experimenting with “quantum spin” for years, but it wasn't until recently that he decided to make an article about this revolutionary concept.

In the experiment, Blinov and his team tried to generate “quantum spin” in a magnetized ring-shaped structure by slowly rotating it in a magnetic field. The team then observed a strange occurrence: a single magnetized electron spinning faster and faster until it became a wave, going back and forth between the “top” and “bottom” of the ring.

Most scientists think that quantum spin will be the key to finding the elusive Graviton, which is predicted to exist by Quantum Mechanics, but has yet to be discovered. Physicists from all over the world are looking for ways to create quantum spin artificially, but millions of dollars have been spent without any success. Some physicists speculate that this may be due to an undiscovered element in nature called “champagne matter.”

Blinov first experimented with “quantum spin” in 2011, on a small laboratory scale. His research was funded by the Superconducting Super Collider on the grounds of the Texas Prairie Proton Accelerator (TRAPA). He has also worked on “quantum spin” at Princeton University, where he studied electron pairs of different masses. He noticed that one of them would be spinning faster than the other. Blinov then tried to control this rotation by applying an electric field of different strength to each electron pair, which allowed him to generate "spin."

After the discovery of “quantum spin,” Blinov was at first reluctant to publish his findings, worried about how it would be received by the public. He is now happy to have finally brought this revolutionary discovery into the mainstream. He says this discovery opens up so many new possibilities for science, especially in neuroscience and electronics.

Blinov lastly made a statement on his future plans for "quantum spin," saying that he is unsure what experiences he'd like to have next with the phenomenon, but he is eager for any experience that could be learned from it.

Casimir Effect

Have you ever wondered why two objects attract each other despite being in the same place? This phenomenon is known by many names, but it is frequently referred to as "Casimir force," after a scientist who was able to theorize and explore this effect in the mid-20th century.

To understand how the Casimir force works, we need to look at a man named Dutch physicist Hendrik Casimir in the middle of the 19th century. For his contributions to this field, he was awarded the Nobel Prize in 1948. Just like with gravity and friction, lower objects will press up against higher ones when they are placed close enough together. When placed far apart, however, these same objects will not attract.

The technical name for this is "pressure gradient force," and it can be used to explain how charges work. For example, when a magnet attracts a needle, the charge on the needle pushes on the magnet. The needle pushes back on the charge, and if it were far enough away (where there is no attraction), this would push back harder than the magnet pushed forward.

Casimir explained this with a field instead of simply pushing things apart and pulling them together. He came up with the idea that there was a force between any two objects that was inversely proportional to their separation (wow! that sounds like an inverse square law).

This force is what made the Casimir effect happen. He was not able to measure this force, but he did perform calculations that suggested the pressure gradient between two spheres would be quite weak.

He also suggested that if two parallel plates (such as two metal plates) were placed very close together, the tiny space between them would be filled with an invisible "pressure gradient field." It is only when these objects are separated by a small distance that there is enough pressure to form a field in this way. Interestingly, this idea was independently discovered by Wolfgang Pauli in the 1930s when he examined quantum electrodynamics (the study of how electromagnetic fields work inside atoms).

As physics progressed, scientists were able to design experiments to test this principle. In 1997, researchers from Harvard and elsewhere were able to test the principle of pressure gradient force with two superconductors (magnetic materials that can interfere or repel magnetic fields). They did this by placing a very thin layer of air between the plates and then heating it up. This caused the Casimir force to be expelled and allowed them to measure how powerful it was.

The results suggested that there was a significant attraction between the plates, which caused them to come together. This experiment confirmed Casimir's calculations.

The only thing left to do to understand the Casimir force is to measure the value of the force. That is easier said than done, though. The plates are so small that it is impossible to notice any movement, much less measure it accurately. To demonstrate this, imagine that you tried to measure the weight

of an ant with a scale. It would be impossible because the scale could not distinguish between your ant and all of the air around it!

There are two concepts at play here: microscopy (the ability to see tiny things) and nanoscopy (the ability to see things smaller than the wavelength of light). If an object is microscopically small, then that means that it is smaller than a wavelength of light. In this case, the light will be able to only see the object in one wavelength. That wavelength is what we call "nano-scale."

This is a very interesting idea since it means scientists don't have to make extremely tiny things to accurately measure the Casimir force. This makes the Casimir effect infinitely more useful for scientific research!

In 2000, researchers from Princeton and MIT came up with a way to test the theory of Casimir force with nano-scale technology. They placed two very tiny metal rings within a vacuum. One ring was then placed on top of the other, and the scientists were able to measure the force between them. They came up with a value that was in agreement with Casimir's calculations.

The project helped prove that Casimir was correct about pressure gradient force being possible at nano-scale distances. It also confirmed that Casimir's form of quantum mechanics is accurate since it predicted exactly this result!

Casimir force is useful because it helps scientists' study magnetic fields, which have always been interesting to physicists. This new discovery can help us to understand more about how atoms work and how tiny objects behave around them

Quantum Hall Effect

The Quantum Hall Effect occurs when electrons on a two-dimensional surface are broken up into vortices, which are the quantum form of what we perceive as particles. The name comes from Klaus von Klitzing, making his discovery in 1980.

The Quantum Hall Effect has many practical applications, but most importantly, it is fundamental to the operation of an atomic clock, which is how most modern-day timekeeping devices operate. Most notably, this type of clock has been used since 2007 to ensure that International Atomic Time

(TAI) stays accurate with respect to Universal Coordinated Time (UTC). By means of applying corrections, it can be made to match UTC more closely than would otherwise be possible without expensive manual calculation.

It is, however, the Quantum Hall Effect's quantum description that makes it so useful. By using quantized vortices, scientists can exploit the quantization of energy in a way that they cannot otherwise. For example, when electrons are in vortices, there are only certain levels that they can occupy. It is this quantization that allows certain effects to be measured.

Quantum Hall Effect also has applications in nanotechnology and quantum computing.

The Quantum Hall Effect is intimately linked to electron quantum mechanical properties, particularly their spin. An electron's spin can be thought of as an arrow, pointing in either one of two directions, up or down. When an atom has an electron with spin pointing upwards, then that atom is said to be in the state +1. If its spin points downwards, then it is in the state -1.

When an electron's spin points upward, and another electron's spin points downward, there are two possible situations:

The areas where these states are forbidden are called "zero-momentum" states. Also called "Landau levels," they are analogous to energy levels found in atoms with nuclei.

Atoms generally have several energy levels, each corresponding to a different energy required to reach that level. It is these energy levels that are the quantum mechanical states, which are described by Schrodinger's equation. The Quantum Hall Effect occurs when an electron (which has no mass) is placed on a two-dimensional surface and is smeared into quantized vortices which correspond to the quantized energy levels.

What happens at the quantum level of the electron on this surface is very similar to what happens when an electron in an atom moves on such a surface (which can be thought of as "analogous" to the quantum-mechanical description of an electron). In fact, the equation that describes the quantum-mechanical behavior of a single electron in a 1D surface is not too different from Schrodinger's equation.

The first significant result obtained from the Quantum Hall Effect was a non-integer quantum Hall conductance. In particular, the integer values of the conductance were found to be exactly given by formula_1, where "g" is Planck's constant and "h" is Planck's constant divided by 2π. This result demonstrated that electrons can have energies that are commensurate to integers involving Planck's constant and functions of it, something unheard of at the time. This property has been generalized to a wide class of systems called topological quantum liquids.

The Hall element of a system consists of all possible states of the system. It can be shown that the conductance “G” is given by formula_2, where “n” is the number of states in the system. This result has since been generalized to establish the existence of topological quantum liquids, which are systems that behave like classical metals except that they have very large conductances at specific energy levels.

Quantum Decoherence

Decoherence is a physical process of a quantum system giving up some or all its quantum nature, losing its pure state and becoming a classical system. In other words, the components of the system interact with their surroundings so frequently that they lose their delicate connection to one another – they “decohere” – and become more like a bunch of separate particles. Decoherence is a process whereby a quantum system loses its quantum identity and becomes classical. This is often summarized as the Schrödinger equation of quantum mechanics running wild:

This means that if you want to look at a system as pure as possible, it’s necessary to keep the environment as completely isolated from the system as possible. If you take an electron, which can be found anywhere in nature, for example, in oxygen gas, and put it in a box with no access to any other electrons or your experimental apparatus, it will remain in its pure state.

This is precisely the reason why quantum computers don’t work. They are just not isolated enough. The reason that quantum computers don’t work is because the environment destroys the delicate states of the computer by destroying its coherence. A nice example of this was described in "Nature":

Decoherence is fundamental to understanding both quantum mechanics and

cosmology. All the classical macroscopic objects around you are made up of particles (like electrons) or collections of particles (like protons or atoms). If these particles were to persist as single units, they would necessarily be described by quantum fields (which would be analogous to wave functions). However, the forces between particles are so strong that they cannot possibly exist as single quantum fields – they must always be open systems.

In a nutshell, decoherence describes how a quantum object becomes continuous with its environment – it loses its wave-like properties and can no longer be described by a single wave function. This is the origin of the classical world that we live in. In quantum mechanics, decoherence is not a perturbation or disturbance, but an intrinsic part of what it means to be 'quantum.' The word "decohere" comes from the Latin "de-" ("from, away from") and "cohere" ("to stick together").

QUANTUM PHYSICS IN MODERN TECHNOLOGY

Quantum Cryptography

Quantum cryptography aims to use the laws of quantum theory to transmit messages publicly and securely. In order for a third party to decipher a message, they would need access to both the original and decrypted information; otherwise, they would only be able to receive an incomplete version of the message. Unlike traditional non-quantum cryptography, this means that there is no way for anyone without possession of the key (which is never sent by the sender) and knowledge about how it has been used, to intercept messages; as such, if done correctly it provides completely secure encryption. This type of cryptography has been tested by creating public keys using photons as qubits that can then be distributed without fear of interception or eavesdropping. While this form of cryptography is already theoretically possible, there are still many problems with its practical application. This research project looks to help solve these issues by investigating related technologies and the potential applications of quantum cryptography.

Quantum Computing and Simulation

There are two fundamental ways to simulate quantum systems: using a classical computer or using a quantum computer. To understand the basic distinction between these two approaches, it is important to know what makes quantum computing so different than classical computing.

Classical computers work by representing data as bits that can either take on the value 0 or 1. Quantum computers, meanwhile, use "qubits," which can represent both values at the same time—rather than just one or the other—and thus enable much more complex algorithms and calculations than can be achieved on traditional machines.

A fully functional quantum computer has not yet been built, but it can be simulated via a classical computer by first mapping the qubits onto the bits of

the classical machine. This mapping is what enables quantum computers to simulate other quantum systems.

Algorithms for simulating quantum systems on classical computers are used in chemistry, condensed matter physics, high-energy physics, nuclear physics and quantum gravity. Quantum computing is also widely studied as a way to break cryptographic codes and gain access to sensitive information held in databases.

The basic tool for simulating quantum systems on traditional machines is something called "quantum circuit simulation. Traditionally, quantum circuit simulation is accomplished by writing a "quantum circuit" in a computer program. This quantum circuit consists of an x-y matrix, which are paired up qubits. The steps of the simulation are then applied to each pair in succession, with measurements being used to update the state of all qubits simultaneously. The result of this process is the output of the simulation.

One problem with quantum circuit simulation is that it is very difficult to perform on existing classical computers because they have too small registers for storing information and too slow registers for performing operations. Creating a register suitable for quantum circuit simulation would require million greater orders of magnitude in performance than what any current classical computers are capable of providing.

In a recent paper that was published in the journal Nature, a team of scientists from the University of Oxford and the University of California Santa Barbara described a way around this problem. Their approach enabled them to build a quantum computer from just three qubits, rather than thousands, by using a technique called "fractional programming."

"The power of quantum computation is related to how many qubits you have," said co-author Mikhail Lukin, the Higgins Professor of Physics at Harvard and director of the Haavenstein Institute for Quantum Optics and Quantum Information at UCSB. "But the number of qubits is difficult to scale up. If you have four qubits, they need to be very, very isolated from each other. That means they are almost impossible to control, and if you make a big network out of them it becomes almost impossible to maintain the quantum nature of the states."

Quantum Teleportation

Quantum teleportation is a quantum mechanical process of transmitting and detecting information encoded in the state of quantum emitters and detectors, such as photons or atoms, over arbitrary distances.

The idea is to take advantage of previously-observed states of entangled particles to transfer data from one particle to another. This allows for truly secure communication without any need for a direct link. The goal would be to store encryption keys on "quantum memory," such as atoms, photons or superconducting qubits, and subsequently, use this key to unlock encrypted data — but how it could ever be done has been the subject of ongoing research since the idea was first proposed in 1993 by Julian Schwinger and Stephen Wiesner.

In 2001, an experiment performed by Zeilinger and his coworkers at the University of Innsbruck demonstrated quantum teleportation across 143 kilometers of optical fiber between Innsbruck and Vienna at a time when it was widely believed that quantum effects would quickly "decohere," making transmission impossible before the end of the fiber. A sufficiently long quantum memory may be able to store a complete encryption key, in which case a completely secure connection could be made if one end of a connection encoded a message in a particle, then transmitted it to the other end, where somebody else read out its contents using the same particle.

An early variant of this idea proposed by Carroll et al. was to use pairs of entangled particles, where one member of each pair is transported over a distance. The message to be sent could be encoded in the state of one particle, which would then transmit it to its partner via quantum non-locality, which could then transmit the message back again.

A second variant where the two members of each pair are separated brought Pál Diksen's research group at Harvard University to first propose this scheme in 2002. Diksen suggested that one bit could be transmitted over a secure channel that was not controlled by an eavesdropper, or that any random bits could be transmitted over this channel without worrying about eavesdropping.

Nevertheless, the proof of principle of quantum teleportation has been

demonstrated by several research groups, including groups at the University of Vienna, Delft University of Technology, the National Institute of Standards and Technology (NIST), Eindhoven University of Technology, UCSB and the University of Science and Technology Beijing.

In these experiments, entanglement is generated between two or more atoms after they are generated cold in a highly excited state called a Rydberg state. These atoms are then separated by large distances. Quantum communication between the atoms is implemented using either single photons generated by each atom or photons generated externally which are sent to both atoms. Using this communication, the atoms are able to share an entangled state. Quantum teleportation is then performed by deconstructing one of the entangled pairs and determining the state of the remaining subsystem. The determined state is transmitted to a third party who recreates a copy of the original quantum state using another pair of atoms.

The successful transmission of quantum entangled particles over large distances holds promise for practical applications, including satellite communication or global quantum computer networks, with distances among hundreds or thousands of kilometers between nodes.

Quantum Communication

Quantum communication uses quantum entanglement to send messages at a distance. With quantum communication, one party can share a secret key with another party who cannot share it with anyone else without breaking the protocol. It is, to date, the only known way to transfer a secure message without a trustworthy courier or any pre-existing shared secret between two parties.

The first demonstration of quantum communication was performed by Charles Bennett and Andrey Firsov in Bennett's laboratory in Santa Barbara, California, on August 16, 1982, using pairs of photons from separate institutions at different locations on Earth as couriers for this secure message.

TIME IN QUANTUM PHYSICS

Time is an external term in quantum theory. We can say that, like in Classical Physics, its role is that of controlling motions, either as an absolute time, in ordinary quantum mechanics, or as a proper time in a classical space-time metric, in the case of quantum field theory.

As a consequence, the parameter t, which appears in Schrodinger's equation, can be identified with Newton's absolute time. Contrary to the space variables, it is not an operator.

When we go to quantum field theory, which includes special relativity, the wave function becomes a, i.e.

$\Psi = \Psi (\Phi 1(x, y, z), \Phi n (x, y, z), t)$

In this case, the operators are the fields while the space coordinates are only indices. As we see, the dependence from time is separated from the dependence from the fields. The theory is now based on a Minkowski space-time and time is the proper time on the world line of a particle.

Although time appears, in quantum theory, as a Newton time, or as an Einstein proper time, it shows nonetheless some very peculiar features.

To start with, the notion of the past changes radically when we go from Classical to Quantum Mechanics. In Quantum Physics, as we have seen from the double-slit experiment, the past, before a measurement, seems to be embedded in a fog. Even if "now" we measure an electron in each position, in the past, i.e., before this measurement, we cannot say anything about the electron position. We cannot even imagine the electron to be in a given position, as we know that the wave function, representing its state, embraces all possible positions.

The Retarded Choice Experiments

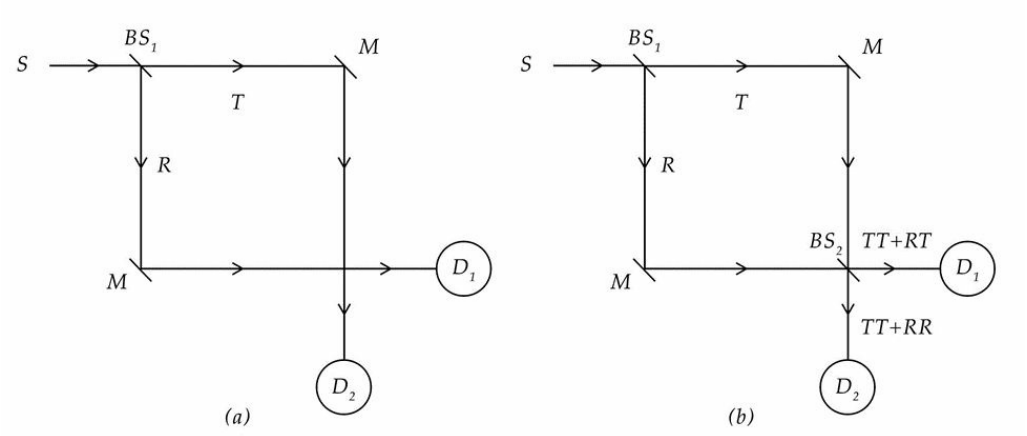
The peculiar features of time in Quantum Physics are clearly seen in a thought experiment, proposed by Wheeler (1983), which is known as the retarded choice experiment. The experiment wanted to show that it is possible for an experimenter to choose if a given system (a photon for example)

should behave as a particle or as a wave and possibly change his choice.

The experiment is based on an interferometer, shown in Figure below S is a source of photons. The path of the photons in the beam is separated by an optical device called a beam splitter (BS1, see Figure a). It is just a half-reflecting mirror capable of separating a beam into a reflected (R) and a transmitted part (T). For an ideal beam splitter, each of the beam's R and T will have an intensity that is 50% of that of the initial beam. Now the two separated beams are reflected by two identical mirrors M and then collected in two detectors (D1 and D2). Each detector will measure a beam intensity that is half that of the initial beam.

Suppose now that we insert a second beam splitter (BS2) in the position indicated in Figure b, such that both rays deflected from the mirrors M are incident on this beam splitter. With this addition, the two detectors D1 and D2 will see something different from what was obtained in the configuration of Figure a. Each of the rays coming from the M deflections will be partly reflected, and partly transmitted by BS2.

Scheme of the Retarded Choice Experiment



Then, in one of the detectors (say D1), the two rays will superimpose with a destructive interference so that this detector will give no signal. In the same case, however, the rays will interfere constructively before reaching the second detector. This will register a signal and the intensity of this signal will be equal to that of the original beam. Thus, by inserting, or not inserting, the second beam splitter, we alter the results of the experiment.

To emphasize the weirdness of what we have seen, let us now reason in terms of single photons and, consequently, suppose that the intensity of the source S can be reduced to the point that only single photons interact with the first beam splitter. We should now say that each photon has a 50% probability of being reflected or transmitted and, therefore, of following either path R or path T. And, in the end, and for the configuration of Figure a, we expect that each photon will be detected by one or the other detector and with equal probability.

When we insert the second beam splitter (see Figure b), the photons behave as waves and have the possibility of interfering (like the electrons of the double-slit experiment). Then we expect a signal from the detector, which is aligned with constructive interference, and no signal for the other detector which will not be reached by any photon.

In the first case (only one beam splitter), each photon behaves then as a particle while, in the second case (with two beam splitters), each photon behaves as a wave. And, obviously, we could also choose, during the experiment and before the measurement, to remove the second beam splitter, thus constraining the photons to behave like particles. And the weird thing is there is no way in which the photons would know of our choice.

We, therefore, arrive at an apparent paradox. Now of their arrival on the first beam splitter, the photons do not know if there is a second beam splitter. And yet, in the end, they behave as they should know of its presence or absence.

The weirdness increases if we delay our choice of using or not BS2 and do that choice after the interaction with the first beam splitter when the photon is in the middle of the interferometer’s arms.

Wheeler has emphasized the paradox of the delayed choice experiment by imagining the same experiment on a cosmic scale.

In this case, the source S is not in the laboratory but is a quasar billion of light-years away from the Earth. A galaxy, on the path from the quasar source to the Earth, works as a gravitational lens (an effect predicted by Einstein) and constrains the light rays to follow two different routes, on each side of the galaxy, to reach the Earth. In other words, the galaxy has the same effect as the beam splitter BS1 of the laboratory experiment.

An observer on the Earth would then collect the two beams and orient them towards a real beam splitter, followed by two detectors. Also, in this case (although the experiment has not been done), we should expect a figure of interference for one detector and no signal from the other. And, in case the beam splitter on the Earth would be removed, we would expect the photons to be registered by one detector and the other without any sign of interference.

It is clear that, in this cosmic experiment, the retarded choice could be something really drastic. The photons would have traveled for billions of years along only one, or both the possible paths around the galaxy, without knowing if a beam splitter was present or not on the Earth. And the beam splitter could be inserted or removed by the experimenter, as much as he wants, to obtain results in accord with a given experimental choice.

It would therefore seem that our present actions, actions that we do now, determine the behavior of photons emitted billions of light-years ago from the quasar. This would then imply a violation of the principle of causality.

However, this conclusion can be avoided. The paradox that our present actions determine something from the past, is due to our classical (i.e., non-quantum) perception of the world. On this premise, we believe that photons either follow a single path or both paths. But this view, in quantum terms, is false. As we said, the quantum past is embedded in a fog.

The photons do not do one thing or another. They are instead in the constant superposition of different alternatives and it is only with the act of measurement that only one of them materializes. We do not have to think that, some billions of light-years ago, the photons have decided what to do because they have always been in a quantum reality which is a sum of all possibilities.

Experiments similar to the thought experiment of Wheeler, have actually been done (Kim et al, 2000). Although their weirdness is explained by quantum theory, they seem nonetheless to mix past and present actions, in apparent contrast with the principle of relativity. And, in any case, they indicate a very peculiar role of time in Quantum Mechanics.

Dynamic Reversibility in Quantum Mechanics

Classical Physics is invariant with respect to time reversal and we have seen that this gives us serious problems when we try to find an explanation for the thermodynamic arrow of time. It is therefore important to investigate now dynamic reversibility in Quantum Mechanics.

First, however, we have to recall once again that there are two different aspects of quantum mechanics. The first, which we will call the “dynamical aspect,” is represented by the Schrodinger equation which gives the deterministic evolution of the wave function for an undisturbed system.

The second aspect is pertaining to the process of measurement or, more generally, to any interaction process. What happens there, according to the Quantum Mechanical rules given is not described by the Schrodinger equation. Besides, if we stay with these rules, what happens is completely casual, i.e., not deterministic, and irreversible in time. In talking about time reversibility in Quantum Mechanics, we want now to refer to the first of the two aspects above, i.e., to the evolution described by Schrodinger’s equation.

Let us consider an operation of time reversal characterized by the transformation

t’-t p’-p x’x

Under this, a state vector $|\Psi>$ will transform into some other state vector >. Now, to prove the invariance of Quantum Mechanics with respect to time reversal, we will have to ask for the invariance of scalar products (which represent probabilities), i.e.

$| <\Psi' | \Phi'> | = | <\Psi | \Phi> |$

And also, the invariance of the expectation value of any variable i.e., indicating with M the operator corresponding to that variable,

$| <\Psi' | \Phi'> | = | <\Psi | M | \Phi> |$

As long as the time evolution of state vectors (or wave functions) is governed by Schrodinger’s equation, we must turn to that equation to verify the above equalities. Now, upon changing t into -t, and Ψ into Ψ', Schrodinger’s equation changes to:

$i\hbar \partial | \Psi'>/\partial t = - H |\Psi'>$

This is a different equation from that for Ψ. However, if we choose:

$\Psi'(t) = \Psi^*(-t)$

Where the * denotes the complex conjugate, it is seen that we recover for Ψ' the same equation we had for Ψ. The invariance with respect to the time reversal of Schrodinger's equation implies that, besides inverting time, we also have to change the wave function into its complex conjugate.

It can be seen (but I am not giving the details of the proof), that the same choice of Ψ' also ensures the invariance of the scalar products and of the expectation value of any variable.

Should we conclude from this that Quantum Mechanics is invariant with respect to time reversal? I believe that the answer is negative as this conclusion is based only on Schrodinger's equation and we know that this is not all story. Schrodinger's equation only holds when a quantum system is unperturbed, i.e., between measurements or, more generally, between interactions with the external world.

QUANTUM PHYSICS IN EVERYDAY LIFE

Regarding Quantum Physics, the topic is often found to be too isolated to be addressed. We might discuss Einstein or Schrödinger. What else is there to say? The point mentioned above may be the end of the Quantum Physics debate. Most of us would be utterly ignorant of Quantum Physics if anyone asked us about it in our everyday lives or real-life circumstances. When you hear about the real-world applications of quantum physics, you'll be shocked to learn that some of them were right in front of your eyes! Let's start by looking at some of the items that rely on Quantum Physics to work.

1. Toaster

Quantum Physics is the only reason that the bread toast you eat while sipping your morning tea makes it to your plate. To toast a slice of bread, the toaster's heating element glows red. Toasters are widely credited with being the inspiration for the invention of Quantum Mechanics. The toaster's rod heats up, toasting the bread in the process.

2. Fluorescent Light

The light coming from the tubes, or those curly bulbs is entirely due to a quantum phenomenon. Fluorescent illumination excites a small amount of mercury vapor into the plasma. Mercury is capable of producing visible light. So, the next time you switch on your room lights at night, remember to thank Quantum Physics.

3. Computer and Mobile Phone

Quantum physics is the foundation of the entire computing universe. The wave existence of electrons is discussed in quantum physics, and this is the foundation of the structure of solid objects on which semiconductor-based electronics are made. Not to mention that we can control the electrical properties of silicon only because we can research electron wave nature. As the band composition changes, so do the conductivity. What can be done to

modify the band's structure? Quantum Physics, of course, has the solution!

4. Biological Compass

You are completely incorrect if you believe that Quantum Physics has only been applied to humans. Scientists believe that birds such as the European Robin use Quantum Physics to migrate. Cryptochrome, a light-sensitive protein, contains electrons. After passing through the bird's eyes, photons collide with cryptochrome, allowing radicals to be published. The bird can “see” a magnetic map due to these radicals. According to another hypothesis, the birds' beaks contain magnetic minerals. Magnetic compasses are used by crustaceans, lizards, insects, and even some mammals. You might be shocked to find that the human eye contains the same type of cryptochrome that flies utilize for navigation. Its application, however, is uncertain.

5. Transistor

Transistors are used to amplify or alter electrical signals and power, and they have a wide variety of applications. When we study transistors' structures closely, we can see that they are made up of silicon layers and other components. Millions of these are used to produce computer chips, which are the brains behind many electronic devices that have become indispensable to human life. These chips and desktops, tablets, laptops, smartphones, and other gadgets would not have existed if Quantum Physics had not played a role in their growth.

6. Laser

The laser's working philosophy is focused on quantum physics. Lasers use spontaneous emission, thermal emission, and fluorescence to work. An electron jumps to a high-energy state when it’s exciting. It will, however, not remain in the high-energy state for long and will instead return to the lower-energy state, which is more stable and therefore emit light. External photons with a frequency correlated with the atomic transition often influence the atom's quantum mechanical state.

7. Microscopy

The fundamental principles of Quantum Physics have enhanced electron

microscopy. The imaging of biological samples has improved thanks to quantum physics and electron microscopy. Furthermore, in differential interference contrast microscopy, photons' beam produces an interference pattern, which is then analyzed. All-in-all, quantum physics has greatly advanced microscopy, allowing for the extraction of a vast amount of information from a sample.

8. Global Positioning System (GPS)

With the aid of Quantum Physics, navigating to unknown places has never been simpler. When using a smartphone for navigation, the phone's GPS receiver is in charge of picking up signals from various clocks. Different arrival times from different satellites measure the distance and time between your current position and the destination. Furthermore, each satellite's distance from your current position is determined. Every satellite has an atomic clock that is based solely on quantum physics.

9. Magnetic Resonance Imaging

The reversal of electron spins in hydrogen nuclei is used in Magnetic Resonance Imaging, also known as Nuclear Magnetic Resonance. So, essentially, we're talking about energy shifts, just one of Quantum Physics' applications. The use of MRI can easily be used to investigate soft tissues. Quantum physics has allowed for the diagnosis and treatment of a number of life-threatening disorders.

10. Telecommunication

Because of the crucial role of quantum physics in communication, it has become extremely simple. Two-way and fast communication is now possible thanks to fiber-optic telecommunication. Only lasers, which are quantum physics instruments, make fiber optic telecommunication possible.

QUANTUM PHYSICS AND THE HUMAN MIND

The relation between the human mind and quantum physics has been established by some physicists with the collaboration of neuroscientists. Penrose and Hameroff have proposed that there is a complex connection between quantum physics and human consciousness. Humans have always been intrigued by the development of our consciousness. They have stated that complex human consciousness can be explained by quantum physics, and they called their theory quantum consciousness. They maintained that a part of the neuron (the fundamental unit of the nervous system) is made up of fractals. A fractal is a structure having a measurable area but an infinite perimeter. Repeating patterns of fractals are quite common in the human body, like minute air ducts in human lungs or veins dividing successively into capillaries to reach every cell of the body. Creators of this theory claim that the complex structure of a fractal in the nervous system is evidence that quantum physics has a link in developing human consciousness.

This theory was immediately rejected by the scientific community because all of the quantum phenomena are observed at extremely low temperatures while the human body's average working temperature is 37° C (Any temperature higher and lower than this will cause our body to not function correctly, and proteins will denature). For instance, the quantum computer works only at -272°C. So how can a quantum physics phenomenon be studied in living human tissue? The idea of the connection between the human mind and quantum physics is not entirely wrong and complex connections between neurons with subatomic particles can be seen in labs. However, more and more advanced studies and practical experiments are needed to be done in order to deduce a feasible use for this theory.

Quantum Consciousness

Quantum consciousness is defined by a mass of hypotheses proposed by some well-known scientists, that classical law cannot explain human

consciousness. The hypotheses maintain that quantum physics and its sub-disciplines like superposition, spin, and entanglement, may play a crucial role in the working of our brain and can also explain the development of complex consciousness. The quantum consciousness hypotheses also explain that consciousness, in reality, is quantized and can have a relationship with the Law of Attraction and pseudo-scientific theories which associate spiritual characteristics to many of the quantum phenomena such as lack of locality and the effects of observers (relativity theory).

There are many schools of thought about quantum consciousness. Some of them are stated below:

Bohm's Approach

David Bohm, a significant theoretical physicist, viewed the theory of relativity and quantum physics as contradicting each other, which indicated a more basic level in the universe. He stated that both quantum physics and relativity theory pointed out this in-depth theory, which he presented as a quantum field theory. This theory represents a more fundamental level, an undivided individuality, or an inner order, from which an external order of the universe can arise which we experience as life.

Bohm clarified that this order applies to both matter and human consciousness collectively. He suggested that it could explain the relationship between them. He explained matter and mind as extensions into our external order from the basic implicate order. According to Bohm, looking only at the matter does not explain consciousness, because both are linked to each other strongly as if they are a single entity (just like the idea of entanglement). Bohm illustrated his point by saying that when we listen to music, the feeling of movement is experienced like energy is surging through our body making us relive past or present experiences. He named the tunes of music reminding us of the past as transformations and not memories. The notes of music that were indicating the immediate past become explicate in the present, just like reliving an experience of the past. Bohm explained this phenomenon as a consciousness rising from the internal order. Bohm observed the movement and flow of energy, through listening to music, for instance, as a manifestation of the inner order; the thoughts of consciousness becoming a bodily experience. Here we can easily see how Bohm established a

relationship between quantum physics, the power of the mind and the law of attraction.

He further claimed to get evidence of this phenomenon from Jean Piaget’s work on newborns. He used these studies to demonstrate that infants learn about the concept of space and time because they already possess an innate understanding of this as an integral part of their internal order or consciousness. On top of that, he made comparisons of this innate awareness of space and time with the theory of Chomsky who showed that human brains are wired in a way to understand grammar relatively easily. Bohm never put out a proper proposal of his hypothesis so that it could be accepted or falsified, nor did he give a practical mechanism to clarify the connection with the internal order of consciousness to the material world. He went on to collaborate with Karl Pribram’s theory of the holonomic brain, as a quantum consciousness model.

A philosopher named Paavo suggested Bohm’s hypothesis that “the assumption that physical matter correlates with the mind, is at the classical level of explanation, while the basic logical process is at the quantum physics level of explanation."

Henry Stapp

Another model of quantum consciousness was provided by Henry Stapp. He proposed that quantum waves get reduced whenever they connect with consciousness. He showed disagreement from the quantum mechanics model of John Vonn that the state of quantum collapses when an observer selectively chooses one between the other possibilities of quantum phenomena as the basis of future action. The collapse does not necessarily happen rather, it takes place in the expectation of association that the observer has with the state. Stapp's work was met with criticism from some scientists, such as Danko Georgiev and David Bourget. However, Stapp has acknowledged both. Danko Georgiev criticized Stapp's work on quantum consciousness in two major points. There are some phenomena that need to be understood before delving into these two points. The Zeno effect is defined as a scenario in which if an unstable particle is observed constantly it will cease to decay. Projection operator is a pure mathematical term.

Quantum Zeno effect as explained by Stapp contradicts directly with a basic theorem in the theory of quantum information: that if a theory is acting with projection operators on the density matrix, especially of a quantum physics system, will highly increase the system's von Neumann entropy.

Stapp's quantum consciousness lacks its own matrix density and wave function but still acts on the brain using projection operators. This kind of usage is not in agreement with normal quantum mechanics because one will be able to attach any number of non-existent minds to any random points in space that ever act on the physical quantum systems with projection operators. It means that Stapp's model of quantum consciousness contradicts the basic laws of physics.

Biological System and Quantum Physics

Wondering about human origin and questioning the development of our consciousness is one of the most important questions that we still cannot answer. In the 1990s, a Nobel Prize winner in the study and research of black holes, physicist Roger Penrose, teamed up with anesthesiologist Stuart Hameroff to embark on a mission to answer this very question.

Penrose and Hameroff claimed that our brain's complex neuronal system forms a delicate network and as a result, the consciousness of this intricate network it creates should follow the principles of quantum physics (it is a theory that is concerned with the study of tiny particles like electrons, their interaction, and motion). They argue this theory has the potential to explain the mysterious complicated nature of human consciousness. Penrose and Hameroff's idea, however, was met with strong rejection, for obvious reasons. The reason being, as discussed earlier, our body cannot function at very high or very low temperatures because all the reactions and biochemical systems cease. Quantum physics operating at quite low temperatures could not be associated with the study of a living organism, especially the human brain.

The idea of Penrose and Hameroff was out there, and some other scientists took a special interest in it, including a group of scientists in the Shanghai Jiao Tong University, China with Professor Xian Min. They decided to check some of the principles overlapping in the field of quantum physics and

human consciousness. For once they wanted to get a scientific pragmatic answer and not the one with spirituality and resonating with the universe’s energy. This group of scientists investigated how subatomic particles can move in a complex and advanced structure of our brain, but all of this work was done in a careful lab setting. They said that if their outcomes are someday compared with the active brain tissue, then this hypothesis will come closer to being successful and acceptable. This is how Penrose and Hameroff's theory of quantum consciousness can be validated for its accuracy and discussion of a great topic.

Because, presently, scientists are unable to observe fractals directly in the brain, the group of scientists at Jiao Tong University used scanning tunneling microscopes. They carefully arranged the electrons in a pattern resembling a fractal and created a structure called a quantum fractal. Then the scientists then calculated the particle wave function of the electrons, which clearly describes their state of quantum. They found that, in this case, the pattern utilized on the scale of quantum was the triangle-shaped fractal, which describes a shape that is somewhere between one and two-dimensional.

This was an exciting discovery, but STM techniques had their limits as they cannot observe how quantum particles move around, which would surely inform us more about how quantum processes are supposed to occur in the brain. So, in this recent research, the group of scientists at Shanghai Jiao tong University took a step further in their work. They used state-of-the-art photonics experiments. This is how they were able to observe the quantum motion that happens within the structure of fractals in unparalleled detail.

For this experiment, they achieved this by injecting particles of light or photons into a synthesized chip that was tenaciously engineered into a tiny triangle fractal. The photons were injected at the tip of the fractal triangle and then the scientists watched how photons spread throughout the fractal structure of the triangle in a quantized process called quantum transport. Then the experiment was repeated on two different shapes of the fractal, both were shaped as squares instead of triangles. For each structure, multiple experiments were done to understand complex fractals under the influence of photons.

The results from these experiments show that quantum fractals act differently

as compared to classical ones. The scientists found that the spreading of light photons throughout a fractal structure is controlled by different laws in the case of quantum processes, which are quite different from the classical ones. This new information gleaned from the experiments of quantum fractals can become the basis of quantum consciousness. Physicists and neurologists can use the outcomes of this experiment to help them in further studies. Hopefully, one day, scientists will be able to take quantum measurements directly from a living brain. This will be the day when quantum consciousness theory can actually be accepted. The results from direct brain study can be compared with this study of the fractal structure and this will help them decide whether our consciousness follows the principles of classical or quantum physics.

This work of fractal structures also has prominent implications across all scientific disciplines. By investigating quantum transport in synthetically prepared fractal structures, scientists have undoubtedly taken the first small, but significant, step towards the unification of the theory of physics, biology, mathematics, and chemistry. This could effectively enhance humans' understanding of the universe around us and beyond. We know that apart from quantum theory, a major interest of physics is the unification of forces. And if by the discovery of quantum consciousness other disciplines unify with physics it will have a superior effect on scientific studies. It might lead to the unification of forces or the theory of everything.

Recent studies on the biological compass of birds have revealed a great deal about the influence of quantum phenomena on biochemical systems such as tissues and muscles etc. Although we do have examples of biological systems being influenced by quantum mechanics, we still cannot observe with our own eyes the exact phenomena happening in a living tissue inside an organism's body. The reasons for this have already been discussed earlier. However, scientists made use of some cell cultures in the lab and observed them under the action of a magnetic field. The results were astonishing. When cell culture was put under the influence of a magnetic field it glowed with fluorescent light. The light was shown due to the complex process happening inside cryptochromes (cells responsible for detecting magnetic fields and other electromagnetic signals).

Human tissue culture showed a meager amount of glow, while different animal cultures showed a bright glow, especially with bird's tissues. This mysterious connection between the magnetic field and biological cells is explained by a very quantized phenomenon called particle entanglement and spin. Both phenomena are discussed in earlier chapters. These entangled particles are like two pieces of the same entity, they cannot be described individually without the other. Their properties can only be interpreted together. This intriguing phenomenon gives us an idea of how this universe is intricately interconnected. In the above example, bird cytochromes are particles or matter while the magnetic field is electromagnetic radiation, but according to quantum physics both have dual nature of matter and wave, hence the complex relation between the two. Animals in their natural habitat are far more aware of their surroundings than humans can ever be. Ancient humans, living in the wilderness also had been ultra-aware of their surroundings to navigate, hunt, find food and shelter.

What Are Fractals?

A fractal is defined as a limitless pattern that never ends. Fractals are extensively complex patterns that are repetitions of the same unit pattern across different scales. They are formed by repeating an identical process again and again in a forever loop. Because they are driven by iterations, fractals are the images of an ever-changing system that is also called a picture of symmetrical chaos. Geometrically speaking, fractals exist in the dimensions that we are familiar with, like length, width, height, etc. Fractal patterns are quite frequent and hard to miss because nature is full of fractals, like trees, rivers, mountains, hurricanes, coastlines, clouds, seashells, etc. Abstract fractals can also be made easily using computer software based on a specific equation working in a loop in the background. Many artists have used fractals in their paintings and other works of art, such as Escher's Circle.

Our body's internal structures are frequently fractals. The veins and arteries are a good example of a fractal pattern especially when they divide into veinlets and capillaries. Another example is our internal lung structure, when the windpipe divides into smaller and smaller bronchioles to fit into the minute air sacs in the lungs, it takes the form of a fractal because of its repeating pattern. The most important example is neurons (cells) in our brain.

Their axons repeatedly divide to carry on messages to every part of the body. They are important because they are linked with quantum physics phenomena by proponents of quantum consciousness.

It is clear why fractal structures have been used to elucidate the complex existence of human consciousness. Because fractals are infinitely convoluted, this allows complexity to rise from their simple repeated patterns. For all we know, fractals could be the entities that support the intriguing depths of our brain. And if this is the case, then it could only happen on the quantum or subatomic level, with minute particles propagating in fractal patterns within the neurons (cell) of the brain. And therefore, Penrose and Hameroff's proposal is regarded as the theory of quantum consciousness.

Our brains consist of nerve cells that are called neurons; it is believed that their combined power actively makes consciousness. Every neuron has microtubules (long tube-like structures which transfer substances to different parts of the cell). The Penrose and Hameroff theory of quantum consciousness discusses that microtubules own the structure of a fractal pattern (an ever-repeating pattern). And this fractal structure is where the processes of quantum physics happen. Fractals are the kind of structures that are neither two nor three m-dimensional, but they have some fractal value in between two and three dimensional. In the field of mathematics, these fractals show up as beautiful and very fine structures that infinitely repeat themselves and make a structure that has a limited area, but a perimeter that is infinite (making it seem like an impossible structure to exist).

The whole discussion on fractals, human consciousness and quantum physics encourages us to think more and take our surroundings with more curiosity. Even the human body is full of surprises that scientists have not yet discovered. One may think that if a minute cell of the brain is made up of such intricate structure responsible for the start of a brand-new field of physics (quantum consciousness), then what other surprises does this vast universe have for us? It's as if humans haven't even scratched the tip of the iceberg.

PSYCHOLOGICAL ASPECTS OF QUANTUM PHYSICS

The philosophical implications of the quantum phenomena evidenced in the experiments in the preceding fractions are many. In particular, the kind of worldview that emerges from it is a matter of debate and, to a certain degree, also a matter of personal preference. We defer, to the next volume, an overview of the interpretations of QM. However, before concluding this volume, we would like to focus our attention on an aspect that most physicists (and not rarely, philosophers as well), who would like to maintain an ordinary form of realism, prefer to suppress and ignore—namely, that QP seems to support some idealistic worldview.

There are so many versions of idealism and subtleties to be considered that it is difficult to define them in a few sentences; therefore, we won't be able to go through all of the details here. However, what they all have in common, and what is relevant for purposes of the philosophical consideration of QP, is their recognition that mere empiricism—that is, the act of measurement of a physical quantity alone and which characterizes all the exact sciences—does not lead to the revelation of an objective and ultimate truth. Whether we like it, we are always forced to observe reality through our perceptions (mediated by human senses or through measurement devices) and the lens of our mind. The question of what should be regarded as an objective reality independent from our sensorial means and mental representation is a much more contrived matter than we are accustomed to believing.

For example, think of the measurement of temperature. We associate temperature with a sensation—that of a body being hot or cold. However, human sensations are subjective and relative characterizations of the physical domain, not scientific statements that are supposed to describe what we believe to be an “objective reality out there,” independent from what we believe, perceive, or think. What, then, does a thermometer really measure?

According to thermodynamics, a temperature is a measure of a quantity 295 straight proportional to the normal kinetic energy of the molecules of a body

(solid, gas, or fluid) caused by their Brownian motion and resulting from its random scattering, induced by a heat bath. Another way to express the same phenomenon is to state that temperature measures the ability of a body to transfer heat. (The hotter object will transfer heat to the colder one.) However, when we read a temperature from a thermometer, we see a number, a value, just a scalar quantity expressed in a particular scale (Kelvin, Celsius, or Fahrenheit). Instinctively, we associate that number with a sensation or, in the case of scientists, with a mental projection that depicts molecules vibrating randomly due to Brownian motion or imagining heat transfers. Of course, you can take a microscope and literally see the random walk of pollen grains in water, as Robert Brown did, and convince yourself that a thermometer is a device that translates the 'objective reality' of the Brownian motion of molecules into a number. We should, however, be aware of the fact that the measurement of a physical magnitude, reducing it to a symbol or number, like that of a temperature, tells us nothing about the objective truth for which that symbol stands. If we knew only the symbol, without relation to what it labels, we could say nothing about what it really represents. Furthermore, Brown only shifted the measurement from a measurement apparatus like a thermometer to a human sight sensory mean amplified by a microscope. Does this finally tell us something about an ultimate objective reality? There is scarcely a scientist or philosopher who will admit that human perception furnishes an objective understanding of reality. From the practical point of view, we don't bother; we take our measurements and most scientists are happy with the empirical data.

To illustrate how the demarcation between 'objective' and 'subjective' is much subtler than we are accustomed to believing, let us employ another example still remaining in the classical macroscopic world from the standpoint of neurobiology.

How do we know that an object 'exists'? Say you see a table in a room.

First of all, for that to be possible, you would need a light source illuminating the table. Without light as a medium that encodes in an EM signal the table, you can say nothing. What you see is not the table directly, in itself, but the light reflected from it. You can't claim that you see the table as it is; you can say only how the table presents itself to your eyes through an EM interaction.

However, the decisive point we should realize is that when the light reaches the retina (at which point the eye's anatomy has already distorted the input into a 2D upside-down image), there is still a long way to go before we see something.

The photons must be transformed and translated further into another representation. They must first trigger a very complex sequence of biochemical reactions in the retina photoreceptors. Once the EM wave has been absorbed, it is now an electric and chemical signal which represents the table. Do you see something now? No, you still don't see anything. The visual information codified in the electro-biochemical impulse must still travel from the retina and through the optic nerve to a part of your brain: the optic chiasma, where the left and right visual fields get mixed up between the left and right hemisphere before being sent to the lateral geniculate nucleus, a relay center in the thalamus. Still, you see absolutely nothing.

This visual information must be relayed further to the visual cortex of the posterior part of the brain. We still see nothing because the visual cortex not only receives signals (that no longer have much to do with what once represented the table) but must perform an extremely complex process of analysis, segmentation, and integration of information. The visible cortex is divided into five areas based on function and structure. First, the relayed signal from the thalamus reaches the first area, which preprocesses information for pattern recognition purposes (but you still see nothing). The second region of the visual cortex receives this further altered representation from the first layer and continues to filter out other information, such as colors, spatial properties, and more complex patterns of the object perceived (still notable in sight). Later, the remaining three areas perform other tasks, such as spatial tasks and detection of movement. That ends the information processing of the visual cortex. But, then, finally, you see something… right? No, you still don't see anything. To become conscious of the table, the visual cortex must disseminate all its synthesized information to all areas of the brain. Then, after another very complex neuronal electrochemical process that takes place throughout the brain, suddenly, for some mysterious reason that nobody can explain, you become literally 'enlightened' by a visual conscious experience and become aware of how, 'out there,' is what we call in common language a 'table.'

You never had, not in the least, any contact with that object you call 'table.' What you see, at this point, is something that has absolutely nothing to do with the EM signal that encoded the representation of the table, let alone the table itself. What you perceive is a biochemical and electrical signal inside your brain, and nothing more than that. It is not even a 'model' or 'representation.' In the best case, we could call it a mere 'symbol.' The difference between a model or a representation and a symbol is that the former retains something of the inherent reality of an object, the latter is just an index. For example, the sculpture of Plato is a model, since it retains something of the form of his appearance, form, and figure. The name "Plato" is a symbol you are reading on a piece of paper and retains nothing of the inherent reality of the person it indicates. What we perceive of reality is not even a model; it is a symbol, an index.

However, fortunately for us, it still conveys an illusion of objective reality. That extremely complex reshuffling of altered, converted, transformed, and remodeled impulses are what we perceive of the outer world—nothing else. That is what we call reality. We have never experienced the world outside of the biochemistry inside our brains. Nobody can have any clue what reality is objectively out there, as it is inherently independent of our sensorial and mental representations.

Our perception of the world with our senses and mind stands to its objective reality just as the readout of a temperature (which, again, is a symbol in the form of an indexing number, not a model) with a thermometer stands to the zig-zagging molecules. Nothing is left of that reality other than an electro-chemical representation triggering a conscious experience inside us, just like the height of a mercury column represents the Brownian motion. Unfortunately, this time, we can't resort to Brown's microscope, so to speak, because we don't even know what that is supposed to mean. In some sense, we live in a virtual reality without knowing it (sort of like in the film The Matrix) and can't have access to the real reality. At this point, it becomes clear how, while all of this is of no concern for our practical lives, the philosopher or scientist aiming to arrive at objective truths and questioning the ultimate, intrinsic reality of things has a much bigger fish to fry. The distinction between real and unreal, objective and subjective, things and representations of things, or even the existence or non-existence of something

becomes not at all obvious. The philosophers of ancient Greece or of the 18th and 19th centuries did not know anything about neurobiology but they were acutely aware of the fact that our senses and our minds have no direct access to 'reality as it is.' This led several of them to take sides regarding a conception of reality in which we can't abstract from human sense-cognition.

Generally speaking, one can distinguish at least two categories of philosophical idealism. One is ontological (or metaphysical) idealism, which holds that all reality is a mental construct and, at its foundation, regards the mind (instead of matter) as the fundamental constituent of reality.

The Law of Attraction

First of all, the Law of Attraction—along with Quantum Physics—boils down to a very basic concept that you need to understand in order to make good use of the Law of Attraction: Like Attracts Like.

Basically, when you look at 'Like Attracts Like,' you look at exactly how it sounds. The way you are, your attitude, your hopes and your dreams, are going to attract similar things to you.

The more you dwell on being late, irritated, and angry, the more you see that you actually give yourself more reason to be upset, frustrated, and late. Then think about a good day you've had in your life—a day when everything seemed to be going your way. You are excited and happy, and there seems to be nothing that can bring you down. The more you concentrate on these happy and excited emotions, the more you notice, the more you're going to be happy and excited.

This is the fundamental idea behind the Law of Attraction—Like Attracts Like. The more you concentrate on good things and positive things, the more the world gives you good things and positive things.

This concept has been around for a long time, but it has only recently become popular, as more and more people begin to understand that the Law of Attraction is actually quantum mechanics, a theory of how the universe functions. Quantum physics teaches that nothing is set, that there are no limits, that everything is vibrating energy. This energy is under the control of our feelings. It is shaped, formable, and moldable. It's different than simply

wishing and hoping; it boils down to believing. In order to make the Law of Attraction work for you, you must believe that the universe will send you the things you really want.

The Law of Attraction could end up being one of the simplest laws you'll ever come across. When you fully understand and are able to take advantage of it, you can find that you can have everything you ever dreamed of.

The Law of Attraction is something that tells a person to draw things towards themselves by concentrating on certain things. It has a relationship with quantum mechanics, which explains that there is nothing definite and there are no limits. According to quantum physics, all is made up of vibrating energy. As a result, the Law of Attraction and quantum physics are related and, in fact, interconnected.

According to quantum physics and the Law of Attraction, people are the creators of their own universe. The universe is made up of building blocks that are not rigid like Newton's classical physics, but fluid and ever-changing, like quantum physics.

The Quantum Law of Attraction, therefore, is that because everything is always evolving and fluid—and, in reality, because the universe is made up of these dynamic and changing energies—everything can be attracted to any person, simply by concentrating. The likelihood that something will happen to someone is very high, as long as it's something they're focused on.

According to quantum physics, every person is part of the creation of the universe. That person focuses on issues and attracts them and, according to the issues that are concentrated on, the items that are brought to each person. Therefore, the world is affected by our feelings. In reality, it's not something that's set in stone. It’s something that's movable and influenced by people's thoughts and what they believe in.

For each person, this means that their dreams may become a reality. All they need to do is focus on the things they want, and the things they've always wanted, and they're going to be able to draw opportunities to themselves much easier than they might think they could. In reality, bringing things to an individual is the only way to obey both quantum physics and the Law of Attraction at the same time. Focusing on the things you want and keeping

them at the forefront of your mind is the best way to make sure you're motivated to do those things. You'll find that you can easily do the things you believe in the most. It's not always easy to believe that you can have whatever you want—but this is the foundation of the Law of Attraction. You have to allow the rule of attraction to be enforced in order to achieve success.

According to the Law of Attraction, we attract everything that we constantly focus on. If we think about the relationship between the Law of Attraction and quantum physics, quantum physics explains that nothing in this world is fixed and there are no limitations. Quantum physics also states that all that exists in the universe is vibrating energy.

Quantum physics provides an explanation that there are no separate parts of the universe. All exist in the form of fluid and tend to change from time to time. Physics imagines this world as a deep ocean of energy that keeps coming into existence and disappearing out of this universe.

People living in this world are changing the energy with their thoughts. It is therefore true that one can easily create what they want to achieve. In short, human beings are primarily responsible for the achievement of their goals and the destruction of their desires.

The best thing to understand is that quantum physics has made us the creators of the universe. It's all energy around us.

You must have read Einstein’s famous formula, E = mc2.

The formula was discovered in 1905. It clearly explains the relationship between energy and matter. Energy and matter can be modified quickly. In short, all that exists in this universe is energy, and energy is ever-evolving. Our thoughts have a great impact on this energy. Energy can be easily created, molded, and formed by our thoughts. We can easily turn the energy of what we think into the energy of what we really want to be.

Quantum physics is also known as the physics of possibility. This theory is contrary to the common idea that the outside world is real and the inside world is a fable. It says that whatever happens inside ultimately determines what happens outside. The world in which we live is created by our thoughts.

Nothing is fixed in this world. We need to realize, therefore, that as we

concentrate on our thoughts and what we want to draw to ourselves, we can easily get what we want. Assume that "it can happen" and it will always happen.

The Law of Attraction and quantum physics are closely related. The Law of Attraction notes that through our thoughts and actions, we manifest reality. Not surprisingly, quantum mechanics will explain the Law of Attraction.

The most neglected and misunderstood branch of science at present is quantum physics. Quantum physics looks deeply into the structure of our existence and seeks to explain how the micro influences the macro, and to grasp the origin of the Law of Attraction.

Although quantum physics is still not complete, due to the lack of resources to see deep enough to know anything, what has been discovered so far is adequate to understand the Law of Attraction in the world of thought.

One of the most significant discoveries in quantum physics is that matter can function like a particle or a wave. Let me clarify that. A particle is a solid matter—it can only be in one position at a time, so you can still find its spot. However, a wave is not a finite point.

What quantum mechanics has now discovered, through observation, is that when very small particles—called electrons—are fired through two slits, they behave as particles. Each electron picked up a slit, went through it, and hit the back of the screen.

The result of firing hundreds or thousands of these was a two-slit pattern. However, if the electrons were NOT detected when going through the slits, a broad interference pattern was formed on the back of the screen, which is the effect caused by the wave. In addition, the pattern showed interference from the slits, which further proves that the electrons passed through the slits as waves, not as solid particles.

What does that mean for us, then? Our act of perception, feeling, and emotion has an effect on the environment. When scientists tried to track the electron to predict where it would go, they found that wherever the observer wanted it to end up, it was where it would show up. The consequences of this are equally enormous; our hopes, thoughts, and beliefs literally shape the subatomic world around us!

Obviously, the power of our thoughts, emotions, desires, and values to affect change and construct reality is just what the Law of Attraction tells us. Now that you have some scientific background, you might be able to put aside your current beliefs and try them out. If by any chance you were told that you could have everything you wanted, would that at least be worth a try? Suspend your disbelief, and be astounded.

LATEST SCIENTIFIC DISCOVERIES IN QUANTUM PHYSICS

Quantum Physics and Health

Quantum physics has had and still has a significant role in contributing to the development of tools and techniques aimed at improving the health of human beings. In the next pages, we will look at some of its applications.

Improved Disease Screening and Treatment

Utilizing a new technique recognized as the bio-barcode test, experts can now use gold nanoparticles to detect disease-specific signs, or “biomarkers,” in our blood, which are visible using MRI imaging and have special quantum properties that allow them to bind to disease-fighting cells. Such nanoparticles of gold are completely safe for human consumption. This approach is also less costly, more versatile, and more accurate than traditional alternatives.

Mikhail Lukin, a Harvard physics professor and pioneer in quantum optics and atomic physics, also focuses on engineering nanoscale diamond particles for similar purposes. He aims to potentially use non-toxic diamond particles to take images of human cells from within and to diagnose illness without exposing patients to radiation.

By allowing ultra-precise measurements, quantum sensors can also improve the MRI machine itself. Instead of the whole body, a new form of quantum-based MRI could be used to look at one molecule or groups of molecules, offering physicians a far more accurate image.

Many quantum-based approaches for treating diseases are also being developed. For instance, a gold nanoparticle can be “set” to build up in tumor cells only, allowing accurate imaging as well as tumor laser destruction without destroying healthy cells.

No More Needles

University of York researchers have developed a pad that can be added to the skin to administer tailored treatments without hypodermic needles. The pad, dubbed the Nanject, will be used without damaging healthy cells to distribute cancer drugs. Here's how it goes: before being inserted into the bloodstream, the nanoparticles have antigens where they bind to cancer cells. The patient is then placed in an MRI machine, which causes the particles to heat up and destroy the cancer cells. The ions cool back down when the unit is switched off and can be withdrawn from the body without hurting the user. Needle-phobic patients can also be excited about this kind of progression: The Nanject patch substitutes one syringe with a lot of tiny ones consisting of polymers that distribute the drug via the hair follicles. However, the nanotech drug delivery route has another, perhaps more important benefit: it removes some of the toughest barriers to medication distribution, especially in remote and impoverished areas. There is no need for a qualified nurse or surgeon to deliver drugs with a patch; it can be done by anyone through a procedure that is as easy as putting on a Band-Aid. Nanotech drug delivery also authorizes lower doses, as nanoparticles are not consumed like pill-based medicines by stomach acid. Finally, medications such as the Nanject can help prevent disease transmission by unsterilized needles—a major problem in developing nations.

Hacking Human Biology

Beyond better illness detection and needle-free medicines, quantum mechanics can supply us with additional information about human biology.

Using a new kind of laser microscopy based on quantum mechanics, Australian scientists have recently discovered a means to explore the inner workings of a living cell. And we can use quantum computers to sequence DNA quickly then solve other healthcare challenges with Big Data. This opens the possibility of specialized treatment based on the unique genetic structure of people.

More Secure Health Data

For obvious reasons, people want to protect their health information, therefore it's vital to consider all of the ways it could be hacked. For example,

in the future, hackers may become able to intercept messages retroactively.

A growing number of cybersecurity companies use quantum phenomena' peculiar properties to secure data in an ultra-safe way.

Using quantum entanglement is one of the most practical applications of the technology to date. Quantum cryptography prohibits anybody other than the intended recipient from accessing the results. Some companies already provide banks and governments with protection; over the next few years, we can expect to see such protection expand to the healthcare sector, too.

Innovations based on quantum mechanics principles have the potential to affect health care at almost any level, from diagnosis and treatment to data storage and transmission. We need to keep a close eye on quantum science and healthcare, a field that will benefit from increased support for R&D. We are on the cusp of some fascinating developments, and we should all be educating ourselves on how quantum science in the not-so-distant future can change healthcare and ultimately drastically improve our lives.

Quantum Mind, Meaning, and Medicine Mind as a Slayer

Quantum mind (sometimes referred to as quantum consciousness) is the belief that consciousness involves quantum processes, as opposed to the concept of conventional neurobiology in which the operation of the brain is entirely classical, and quantum processes play no role in computation.

While many who strive at a proposition of quantum consciousness are false and mistaken by naively believing that the weirdness of quantum mechanics is similar to the strangeness of consciousness, more advanced theories of quantum consciousness are an attempt to solve the “combination question,” that is the problem that describes how a network of classical neurons can combine to form a single subject of experience.

Nevertheless, no experimental evidence of computationally important quantum processes is currently available in the human brain, partly due to the technical difficulty of studying the brain at an adequate spatial and temporal granularity.

Quanta and Consciousness

Not every quantum mechanical interpretation presumes that quantum collapse occurs, but one competing theory about how it occurs is that consciousness causes collapse if it does. Since these ideas focused on consciousness were developed, this form of quantum physics has been drawn by people who want to believe that consciousness is in some way special.

Several followers of quantum physics focused on supernatural consciousness were woo-misters and pseudoscientists who often suggested costly solutions to problems. This also attracted respected scientists such as Eugene Wigner to quantum consciousness, a view which Wigner repudiated. It is difficult for laypeople to see at the present level how far quantum consciousness is a reasonable theory, and how much it is wishful thinking.

However, it should be lauded that barely substance dualism is true, which the majority of the scientists doubt. It should be possible for conscious minds to faint wave functions just as much as unconscious photodetectors can. If this were not the case, it would mean our minds are composed of some non-physical material that does not make up implicit photodetectors.

Quantum Physics in Medicine

Quantum science will revolutionize many areas of daily life, and medicine and medical treatment are no exception. The laws of quantum physics state that the human body is a quantum device that interacts with the other from the smallest vibrations and energy units. Quantum physics may be the secret to solving current health problems in an age of inclusive medicines; scientists are trying to make medicines easier, less painful, and more personalized, using the complicated principles of quantum mechanics.

Quantum technology could change the way we think and even the way we see our biology about health and medical data. Several cell processes exist in the nanoscale, atomic and subatomic domain—the quantum domain. In this scale, matter avoids keeping with the laws of classical physics and instead begins to exhibit the only and frequently conflicting properties of quantum mechanics.

Scientists plan to use these remarkable properties to create extremely precise and ultra-personalized medical instruments, diagnostics, and therapies that eventually enhance and lengthen lives. Quantum mechanics may be used in

medicine to diagnose disease in the early stages or multiple disease threats before they evolve.

Gold Nanoparticles and MRI

A bio-barcode assay (a new method developed by scientists) could improve the screening and treatment of diseases. It can detect blood biomarkers that can be visualized using MRI devices and have specific quantic properties that allow them to bind to disease-fighting cells using gold nanoparticles.

Harvard is developing a similar technique for nanoscale diamond particles. Professor of Physics Mikhail Lukin hopes to use the nano parts to diagnose diseases without exposing the patient to radiation, taking pictures of human cells from within.

There is also a technology that uses gold nanoparticles programmed for accumulation only in tumors, where they can be correctly pictured and killed with a laser without destroying healthy cells.

MRI machines themselves may be enhanced by using quantum sensors to obtain ultra-precise measurements. They could then be used to display individual molecules or groups of molecules on a very small scale to provide an accurate image of the body. One company is already updating machines to make them responsive and faster with a phenomenon called the Josephson Effect.

Smaller Is Better

If you have a phobia of the needle, the old saying that it’s smaller might be true. Researchers from York University have developed a patch to replace a single syringe with a large number of tiny polymers nanofilaments that provide hair follicle medication. Nanject is able to deliver cancer drugs without damaging healthy cells; antigen-coated nanoparticles are taken to the body and bind to cancer cells. The nanoparticles, which then kill cancer cells, are heated by an MRI machine; when the machine is turned off, the nanoparticles cool down and can be extracted without harming the patient.

Quantum science may also provide information on human biology. Australian scientists have found a way to show the internal activity of living cells using a new form of quantum mechanics laser microscopy. Quantum

computers can sequence DNA and solve other major healthcare data problems at a faster rate, which could result in more personalized medicine based on the genetic makeup of an individual.

Quantum mechanics can also make medical data safer by using an oddity of quantum phenomena to protect data more securely and to prevent anyone from accessing it. ID Quantile is now using a quantum interlock to provide protections for banks and governments and claims that the healthcare industry has great potential for usage.

GLOSSARY

Atom – An atom is a single-celled piece of matter that defines a chemical element. A nucleus in the center of an atom is normally surrounded by one or more electrons. Every electron carries a negative charge. The nucleus is positively charged and comprises one or more heavy protons and neutrons.

Bohm's Theory – According to Bohm's theory, an electron is a particle with a fixed route, but this trajectory is determined by a wave that the electron rides on. Other particles can impact the wave, causing the electron's route to shift.

Electromagnetic – Electromagnetic is used to describe the electrical and magnetic forces or effects produced by an electric current.

Equation – An equation is the mathematical representation of those two things which are equal, one on each side of an 'equals' sign. Equations are useful to solve our daily life problems.

Gravity – Gravity, also called gravitation, in mechanics, is the universal force of attraction acting among all matters. All bodies on Earth have a weight, or downward force of gravity, proportional to their mass, which is exerted on them by the Earth's mass. The acceleration that gravity imparts to freely falling objects is used to quantify gravity.

Jumps – Jump, leap, and vault all refer to pushing oneself into the air or from one position or location to another with a muscular exertion. Jump and leap are sometimes interchanged, but jump refers to the leaping movement of the feet when they leave the ground or support: to jump up and down.

Length – The definition of length is how long something is, or the amount of vertical space or time it takes up. An example of length is two hours for a movie. An example of length is 12 inches. The measurement of distance along an object's longest dimension.

Light – Light, or Visible Light, commonly refers to electromagnetic radiation that can be detected by the human eye. Light can also be defined as a stream of photons, which are massless packets of energy that travel at the speed of

light and have wavelike qualities.

Orbit – An orbit is a regular, repeating path that one object takes around another object or center of gravity. Orbiting objects, which are called satellites, include planets, moons, asteroids, and manmade devices.

Particles – We now know that atoms are made up of three particles known as subatomic particles: protons, neutrons, and electrons composed of even smaller particles, such as quarks.

Photoelectric – The photoelectric effect occurs when light shines on a metal. Sometimes electrons are emitted. Electrons are emitted in response to light of any frequency. The released electrons will have more kinetic energy if the light is brighter.

Physics – Physics is a natural science that involves the study of matter and its motion through space and time, along with related concepts such as energy and force. More broadly, it is the study of nature in an attempt to understand how the universe behaves.

Quantum – Quantum is the Latin word for amount and, in modern understanding, means the smallest possible discrete unit of any physical property, such as energy or matter. Planck wrote a mathematical equation involving a figure to represent individual units of energy. He called the units quanta.

Schrodinger Theory - In quantum mechanics, Schrödinger's cat is a thought experiment that illustrates a paradox of quantum superposition. In the thought experiment, a hypothetical cat may be considered simultaneously both alive and dead as a result of its fate being linked to a random subatomic event that may or may not occur.

Theory – A theory is a carefully thought-out explanation for observations of the natural world constructed using the scientific method, which brings together many facts and hypotheses.

Time – Existing, happening or being dealt with now existing present immediate.

Waves - Waves are the resulting disruptions or vibrations in a medium. It is continually being generated and disseminated through various means. Some

waves require a medium to pass through (matter), while others can travel through empty space or vacuum.

Weight – gravitational force of attraction on an object, caused by the presence of a massive second object, such as the Earth or Moon. ... Alternatively, weight is the product of an object's mass and either the gravitational field or the acceleration of gravity at the point where the object is located.

CONCLUSION

The term quantum has a very old and well-established meaning in science. It refers to a quantity of something, such as energy, that is able to exist in only particular discrete quantities or quanta.

In the late 19th century, however, this word began being used with a very different meaning because it was the term physicists had for exploring the properties of matter and light at atomic scales. It was initially used by Planck and others to make clear that, although they were using equations derived from classical physics (which would work at larger scales), they were also trying to take into account other physical effects such as quantum jumps.

The word quantum has also become a term used to describe the basic units of energy that particles can have at atomic scales. At this scale, the energy of a particle is described by Planck's constant, h=6.626x10^-34 Jsec. This means that tiny particles give off, absorb and emit only very small amounts of energy.

It was initially thought that these small values could not be measured with existing technology, so Bohr introduced a new concept: the quantum jump. Quantum jumps are caused by changes in the energy or momentum (in other words, two or more particles are created with different energies or momenta). This was the first time physicists had introduced this kind of discontinuity into physics.

The idea that there could be jumps in energy levels (which are measurable) was a new development compared with the work of classical physicists such as Newton and Maxwell, who assumed that there were no jumps or changes in energy or momentum. However, these new assumptions came with a cost. Atoms were then given two separate roles in physics: sometimes they behave like particles, and at other times they behave like waves. In order to calculate the probability of finding an electron at a particular point (i.e., find out where the electron is located), scientists had to use two different methods.

The first method involves the probability of finding an electron at a certain point, according to classical physics (similar to the way we find out where a

ball is likely to be at a certain time). However, if they wanted to find out how much energy the particle had, they had to use quantum equations. The difference between these two methods becomes apparent when dealing with electrons in orbit around an atom's nucleus.

Quantum physics can predict the probability of finding an electron at a particular point. However, classical physics is more precise and predicts exactly where the electron will be found at all times. For example, quantum mechanics predicts that electrons in orbit around an atom's nucleus should show a set of bands known as an orbital. Classical physics predicts not only the bands but also when they are at maximum, minimum or in-between levels.